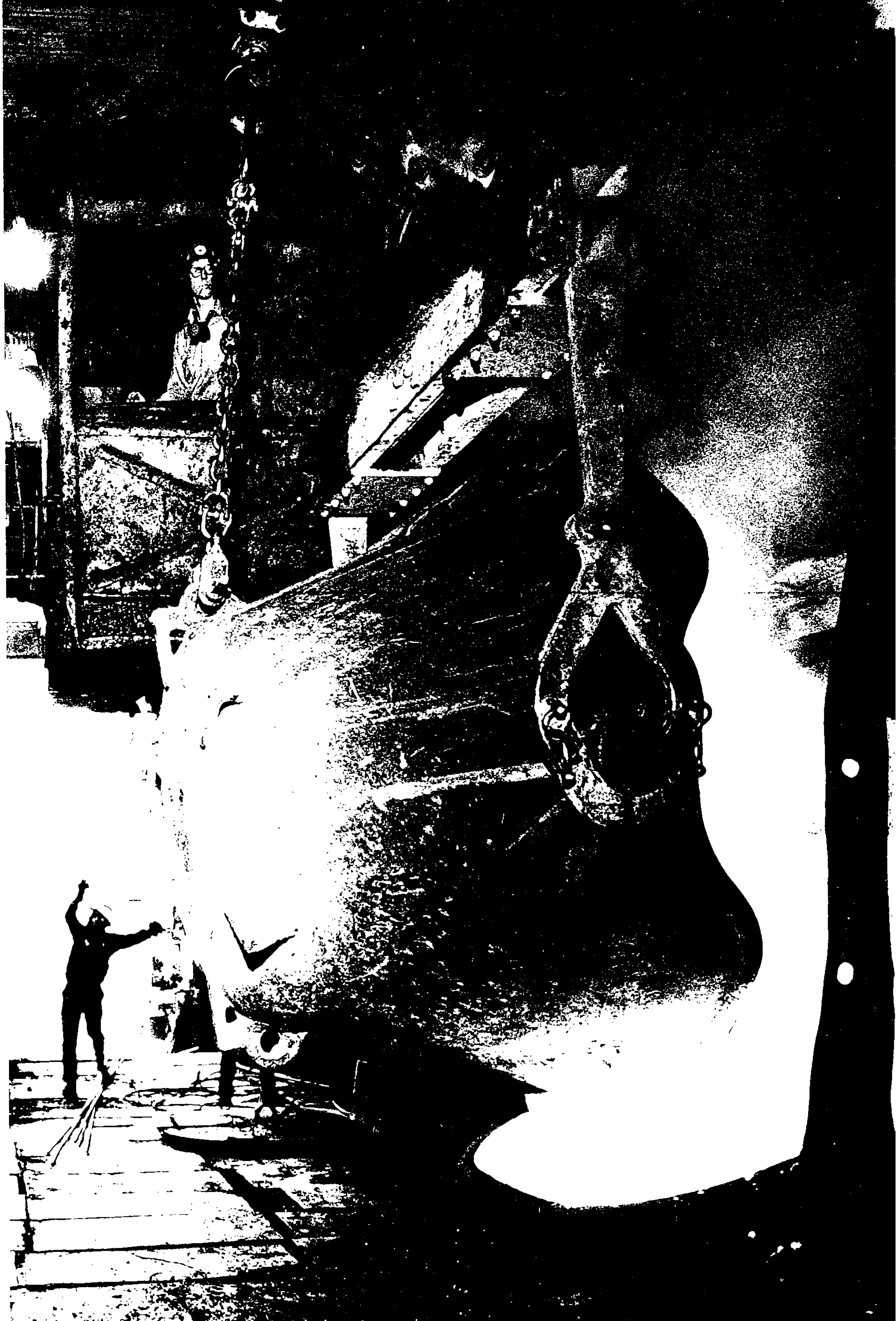
CANADIAN MINERALS YEARBOOK 1976



MINERAL REPORT 26

CANADIAN MINERALS YEARBOOK 1976

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Foreword

This issue of the Canadian Minerals Yearbook is a report of developments in the mineral industry for 1976. The 56 chapters dealing with specific commodities were issued in advance under the title Preprints, Canadian Minerals Yearbook 1976 to provide information as soon as possible to interested persons. The Statistical Summary prepared specifically for the Yearbook each year, deals with the overall position of the industry in its national and international perspective; it comprises 69 statistical tables not readily available from other sources. The Company Index provides full and accurate company names and a complete cross reference to corporate activities in the Canadian industry, supported again by pocket map 900A, Principal Mineral Areas of Canada.

The Yearbook is the permanent official record of the growth of the mineral industry in Canada and is preceded by similar reports under various titles dating back to 1886. Those wishing to refer to previous reports should consult departmental catalogues, available in most libraries.

The basic statistics on Canadian production, trade and consumption were collected by Statistics Canada, unless otherwise stated. Company data were obtained directly from company officials or corporate annual reports by the authors. Market quotations were mainly from standard marketing reports.

The Department of Energy, Mines and Resources is indebted to all who contributed the information necessary to compile this report.

October 1977

Editor: R.B. Abbott
Graphics and Cover: N. Sabolotny

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Readers wishing more recent information than that contained in the present volume should obtain the 1977 series of preprints: a complete set costs $20.00; individual copies sell for 50c and may be obtained from Canadian Government Publishing Centre, Supply and Services Canada, Hull, Quebec, Canada, K1A 0S9. For shipments outside Canada add 20 per cent to prices shown. Prices subject to change without notice.

Front End Leaf

Canada 1976 is symbolized by the vast Olympic Stadium in Montreal, shown here in colour, which was built to accomodate the first Olympic Games ever staged in our country. Capable of seating 72,000 spectators, the structure contains more than 300,000 cubic yards (230 000 cubic metres) of concrete, half of which was utilized in some 9,000 precast members, along with 360 miles (580 kilometres) of prestressed cable. (Photo courtesy Canada Cement Lafarge Ltd.).

Frontispiece

Emptying a massive mobile ladle, an operator carries out a slag pour into a fuming furnace at Cominco Ltd's Trail, B.C. lead smelter. (Cominco photo).

Contents

General Review

W.E. VAN STEENBURGH

The state of the Canadian economy 1976

The recovery in economic activity, which began in 1975, accelerated in the first quarter of 1976. But Canada, in common with all major industrialized countries, experienced a marked retardation in economic growth during the second, third and fourth quarters of the year. This economic pause is likely to make the Canadian recovery cycle one of the weakest on record since The Second World War. At year-end, the strength, and particularly the duration, of the worldwide recovery was very much in doubt. Gross national product (GNP) at market prices for 1976 rose to a level of $190.0 billion, which was 14.9 per cent higher than a year earlier. After discounting for the rise in overall prices, the growth in real GNP was 4.9 per cent. By comparison, real growth amounted to 1.1 per cent for 1975 and 3.7 per cent for 1974. Figure 1 shows the GNP and the GNP per capita from 1955 to 1976, in both current and constant (1971) dollars.

Corporation profits before taxes fell 0.3 per cent in 1976, compared with increases of 7.2 per cent in 1975 and 25.1 per cent in 1974. Profit as a percentage of GNP was 10.6 per cent in 1976. On the other hand, labour income, which accounts for over one-half of GNP, rose 15.0 per cent in 1976. This represented some reduction from the large increases of 19.2 per cent and 18.3 per cent in 1975 and 1974, respectively.

Although overall profits were down slightly in 1976, they varied considerably among industries. Total mining showed increased profits, with metal mines and mineral fuels recording a small increase, and other mining a large increase. Total manufacturing earned slightly decreased profits. Among its components, the primary metal, electrical products, paper and forestry, and chemical industries showed large decreases; the food and beverage, printing and publishing, metal fabricating, machinery, nonmetallic mineral products, and petroleum and coal products industries had little change; while the wood, transportation equipment and textiles industries recorded significant profit increases.

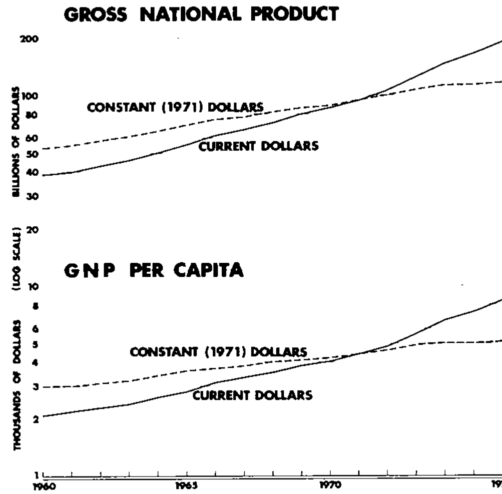


Figure 1

A significant part of corporation profits and of nonfarm unincorporated business income was due to gains in the value of inventories which resulted from the turnover of goods at rising prices. The inventory valuation adjustment, which removes from income those profits which do not reflect current production, amounted to —$2.0 billion in 1976.

Real domestic product (RDP). Figure 2 indicates the growth in RDP for selected Canadian industries since 1960. RDP measures the country's output of goods and services and differs from GNP in that it is a measure of the production rather than the income of Canadians. The RDP index (1971 = 100) for all Canadian industries for 1976 was 124.2, compared with 118.7 a year ago, a rise of 4.6 per cent.

Production of mines, quarries and oil wells for 1976 increased 1.0 per cent from 1975; with metal mines up

Statistical data were compiled by the Information Systems Division of the Department of Energy, Mines and Resources, from information provided by Statistics Canada.

CANADA
REAL DOMESTIC PRODUCT (1971=100)

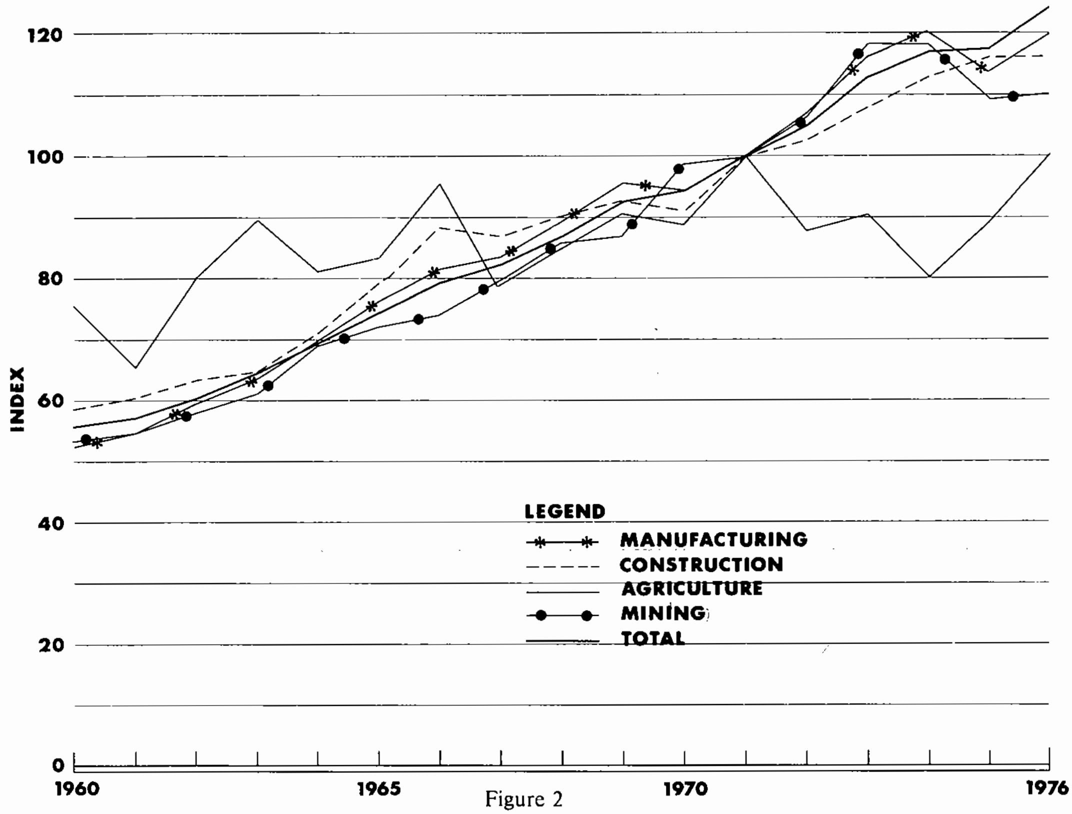


Figure 2

5.4 per cent, nonmetal mines up 14.0 per cent, and mineral fuels down 5.5 per cent. Manufacturing production for 1976 increased by 5.1 per cent from 1975; and among its components the transportation equipment industries were up 10 per cent, chemical up 6.1 per cent, metal fabricating up 5.8 per cent, nonmetallic mineral products up 2.5 per cent and petroleum and coal products up 2.4 per cent; whereas machinery was down 0.5 per cent, and primary metal industries were down 2.9 per cent.

Labour force and unemployment. The year 1976 brought little improvement to the Canadian labour scene. The total labour force increased 2.5 per cent in 1976 to 10.31 million people, from 10.06 million in 1975. The increase was somewhat less than the 3.7 per cent growth in the labour force for the previous year. Employment increased 2.2 per cent in 1976, compared to 1.9 per cent in 1975. The number of unemployed people grew by 39 000 in 1976, to a total of 736 000 people. The unemployment rate increased marginally to 7.1 per cent in 1976, from 6.9 per cent in 1975. Figure 3 is a graph of Canada's population, labour force and unemployment rate from 1955 to 1976.

All regions recorded limited growth in employment in 1976. For example, the increase in British Columbia was 2.9 per cent (29 000 new jobs), Quebec 1.1 per cent (27 000 new jobs), Ontario 2.1 per cent (76 000 new jobs) and the Prairies 4.2 per cent (66 000 new jobs).

The goods-producing sector provided a significant contribution to the growth in employment in 1976, with an increase of 2.8 per cent, or 91 000 people, compared with a decrease of 3.6 per cent in 1975. Employment in the service sector rose by 1.9 per cent or 118 000 people in 1976. Among industries in the goods-producing sector, mining employment showed an increase of 4.3 per cent, or 6 000 people, to a total of 146 000 in 1976, compared with a 10.2 per cent increase in 1975. Manufacturing employment recorded an increase of 2.9 per cent (55 000 more jobs) in 1976 compared with a 6.6 per cent decrease in the previous year. Construction employment increased by 5.3 per cent (32 000 new jobs) in 1976 compared with 2.0 per cent increase a year earlier.

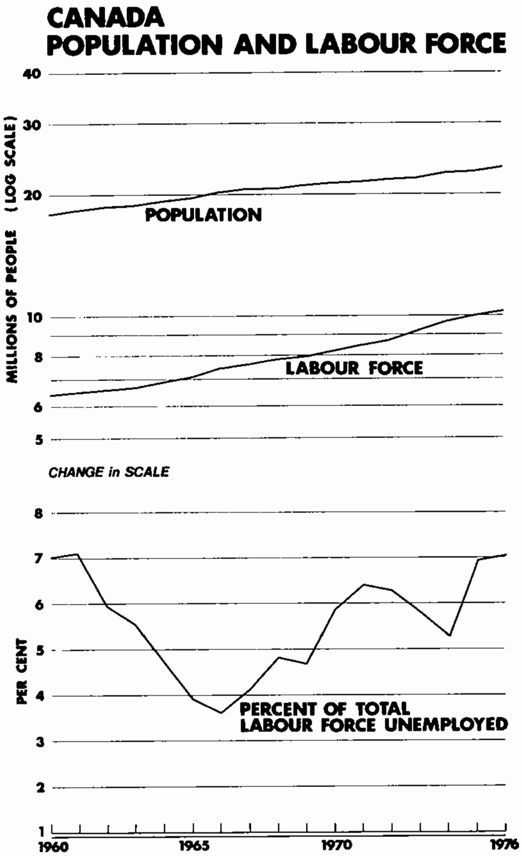


Figure 3

Labour disputes increased significantly in Canada during 1976, with 11.6 million man-days lost in work stoppages*, an increase of 6.4 per cent over 1975. Work stoppages in mines, quarries and oil wells decreased 50.9 per cent to 0.6 million man-days lost in 1976. Continuing inflation, in conjunction with the wage and salary restraint program of the Anti-Inflation Board, contributed to labour unrest.

General prices. Prices at both the retail and wholesale levels rose somewhat less sharply in Canada in 1976, in line with the general easing of inflation in most industrial countries of the world. According to Statistics Canada, inflation** rose at a 9.4 per cent rate in 1976. The moderation in the rate of inflation may be attributed to a variety of factors. The preceding recession and the modest nature of the recovery exercised a dampening effect on the overall rise of prices. Food prices remained relatively stable, and in some cases declined. The federal government exercised restraint in stimulating demand through fiscal and monetary policy, and introduced an anti-inflation program, comprising wage, price and profit controls, in late 1975.

The Consumer Price Index (1971 = 100) which is designed to measure typical family living costs, reached 148.9 for 1976. This was a rise of 7.5 per cent over 1975. From 1975 to 1976, food went up by 2.7 per cent, housing 11.1 per cent, clothing 5.5 per cent, and health-personal care 8.5 per cent.

The purchasing power of the consumer dollar, in terms of 1971 prices, stood at 67 cents for 1976.

Canada's total wholesale price index (1935-39=100) was 512.4 for 1976, a rise of 4.2 per cent over the preceding year. During this period the price of vegetable products fell by 4.2 per cent, textile products increased 9.3 per cent, non-ferrous metals rose 5.7 per cent, nonmetallic minerals rose 10.3 per cent, and iron products increased 8.4 per cent.

Balance of international trade. Canada's current account showed a balance of payments deficit of $4 187 million for 1976. This represented an improvement of $592 million over the record deficit of $4 779 million registered in 1975. The improvement was caused by the balance of merchandise trade, which became positive and amounted to $1 089 million to 1976, an increase of $1 623 million over 1975. The balance for nonmerchandise transactions recorded a deficit of $5 276 million for 1976, a deterioration of $1 031 million from 1975. Trends in the merchandise and non-merchandise trade, and in the current account from 1960 to 1976, are illustrated in Figures 4 and 5.

During 1976, the value of merchandise exports increased to $37 329 million, up 14.8 per cent over 1975. In most cases, this represented an increase in both the volume and the price of exports. One exception was crude materials, inedible, where the value of exports and the price were up but the volume shipped was down slightly, 1.1 per cent, from 1975 to 1976. The value of shipments to Canada's principal markets generally recorded increases. Exports to the United States (U.S.), the European Economic Community (EEC), Japan, Central and South America, Eastern Europe including Russia, and the Middle East, were up. Exports to Asia, excluding Japan; and to Africa, excluding the Middle East; were down. The U.S. market received 67.3 per cent of total shipments in 1976. The largest increase in the value of exports was recorded for live animals. Considering some of the major commodities: the value of wheat exports for 1976 decreased from 1975 and that for barley increased; iron, copper and nickel ores and concentrates increased, whereas zinc in ores and concentrates decreased; natural gas and coal were up, while crude

*In calculating time lost, only the workers directly affected by the strike or lockout are taken into account; time lost by workers indirectly affected, such as those laid off as a result of a work stoppage, is not included.

**Measured by the differences between current-dollar GNP and real GNP.

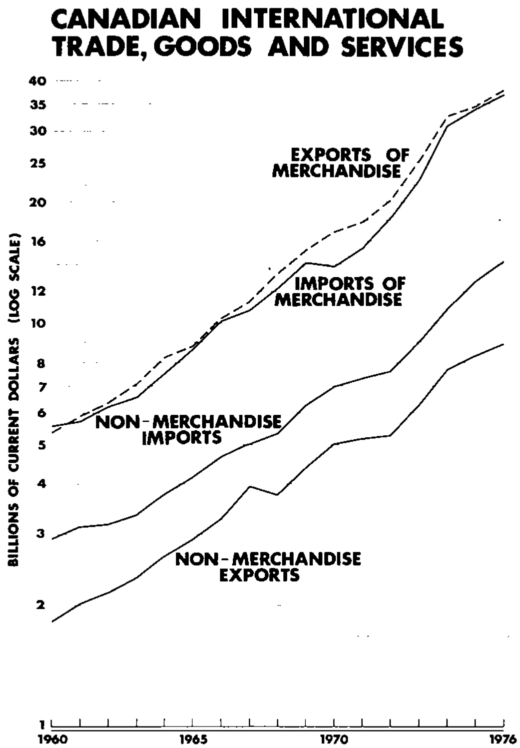


Figure 4

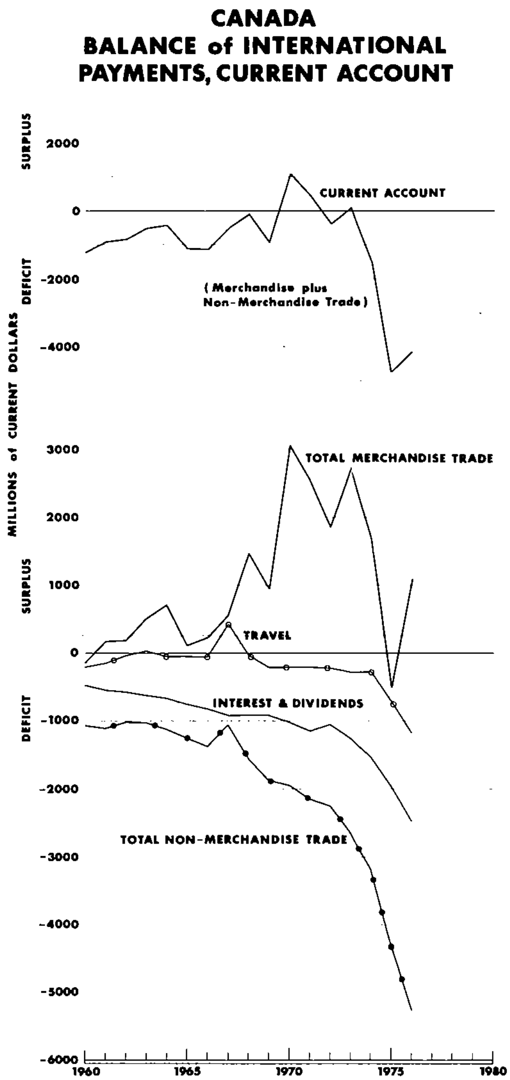


Figure 5

petroleum was down; asbestos showed an increase in exports from 1975 to 1976; lumber, wood pulp, and newsprint paper, fertilizer and inorganic chemicals, aluminum, copper, nickel, zinc and precious metals including alloys, and automobiles, trucks, engines and parts, recorded an increase in exports in 1976.

Merchandise imports increased to $37 469 million in 1976, a growth of 7.7 per cent from 1975. The increase reflected the economic recovery from the 1974-75 recession. The value of imports from the United States, Japan, and central and South America increased in 1976, while those from Western Europe, and the Middle East decreased to some extent. The United States supplied 68.7 per cent of total imports in 1976. Most commodities recorded an increase in imports. Among those groups of commodities whose imports remained approximately the same, or decreased, from 1975 to 1976 were: coal, crude petroleum and related products, non-ferrous metals, metals in ores, concentrates and scrap; crude nonmetallic minerals, petroleum and coal products, and iron and steel products.

The deficit on nonmerchandise transactions worsened by 24.3 per cent from 1975 to 1976, to record a value of $5 276 million. With the exception of freight and shipping, the net balances on all the service items worsened. The largest item was the interest and dividends account, with a $573 million increase in the deficit to $2 491 million.

The deficits on other services and travel increased by $303 million and $464 million respectively, while the deficit on freight and shipping improved by $216 million to $173 million.

During 1976 there were increases in the prices of both exports and imports associated with Canadian and world-wide inflation. The export price index (1971 = 100) for all sections increased to 177.5 for 1976, a rise of 2.4 per cent from 1975, end products, inedible, showed the largest increase of 5.1 per cent, followed by crude materials, inedible, at 4.9 per cent; whereas food, feed, beverages and tobacco recorded a 4.6 per cent decrease. Changes in the export price indexes for some commodities of particular interest were: iron ore and concentrates, up 7.8 per cent; copper ores and concentrates, up 10.0 per cent; crude petroleum, up 10.3 per cent; natural gas, up 21.6 per cent; coal, up 5.5 per cent and asbestos up 13.1 per cent; with wheat down 19.4 per cent and nickel ores and concentrates down 0.4 per cent.

The import price index (1971 = 100) for all sections increased to 158.2 for 1976, a rise of 0.7 per cent from 1975. Changes in the import price indexes for some commodities of particular interest were: fresh fruit, up 1.7 per cent; cocoa, chocolate, coffee and tea, up 54.8 per cent; coal, up 0.2 per cent; crude petroleum, up 1.9 per cent; industrial machinery, up 5.0 per cent and cars, trucks and parts up 2.7 per cent. By contrast, raw sugar was down 37.1 per cent.

Figure 6 illustrates the behaviour of net capital movement in the Canadian balance of international payments for 1955 to 1976. Interest differentials continued to provide a strong incentive for inflows into Canada. The total net capital inflow in 1976 amounted to $4 709 million, a rise of over $335 million from the $4 374 million recorded in 1975. The net inflow of

CANADA, BALANCE OF INTERNATIONAL PAYMENTS, CAPITAL ACCOUNT

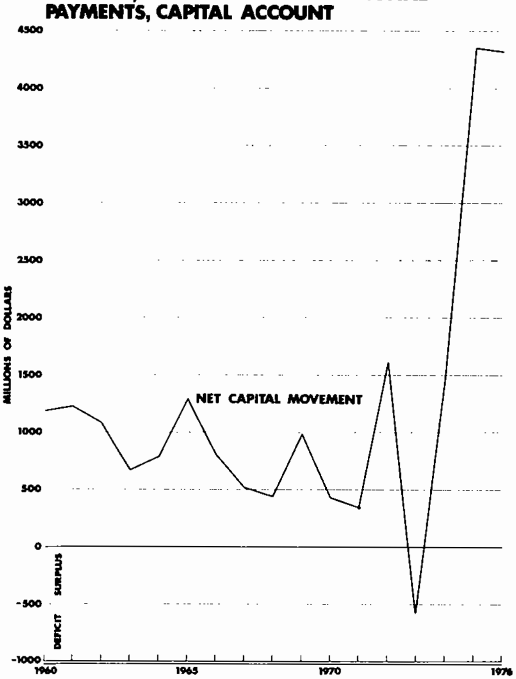


Figure 6

long-term capital in 1976 rose sharply by over $4.0 billion to a record $7.874 billion. This mainly reflected higher portfolio transactions such as increased sales of net new-bond issues by Canadian corporations and the various levels of government to nonresidents. Short-term capital movements in 1976 recorded a net capital outflow of $3 165 million, a deterioration of $3.7 billion from 1975. The main components were transactions through the banking system and the balancing item, both of which recorded a net outflow. The balancing item represents unidentified transactions in both the current and capital account. By convention, it is included with short-term capital movements. It is possible that part of the balancing item represented unidentified outflows associated with the acquisition of foreign securities by residents of Canada, through channels not covered by Statistics Canada surveys. Mineral exports contribute substantially to improving the merchandise trade balance of the current account, but because of data problems the contribution of the mineral industry on net capital movements is not known.

Capital and repair expenditures. Total investment, including both capital and repair expenditures on construction, and machinery and equipment in Canada during 1976, at current prices, was $53.1 billion. This was $4.7 billion, or 9.8 per cent, higher than 1975.

Investments for 1976 were more substantial in the business sector than in the non-business sector. Sectors showing the largest percentage increases in 1976 compared with 1975 were: housing, 33.2 per cent; mining, quarrying and oil wells, 24.7 per cent; agriculture and fishing, 14.4 per cent; the construction industry, 11.8 per cent.

Trends in the total investment in major Canadian industrial sectors from 1955 to 1976 are illustrated in Figure 7. The total investment forecast for 1977 is $57.5 billion, a rise of 8.3 per cent over 1976.

International background

The year 1976 marked a continuation of the worldwide recovery from the most severe economic recession experienced since The Second World War. For most of the major countries belonging to the Organization for Economic Cooperation and Development (OECD), the turning point from the recession came early in 1975. Real output for the OECD countries advanced at an annual rate of 4.5 per cent in the second half of 1975, and then increased to 6 per cent in the first half of 1976. The initial impetus to the recovery came from personal consumption expenditures and inventory accumulation. In addition, the United States, Japan and Canada experienced a substantial housing boom.

As the year progressed, an economic pause set in; personal spending eased, housing construction weakened, and the contribution of inventory accumulation

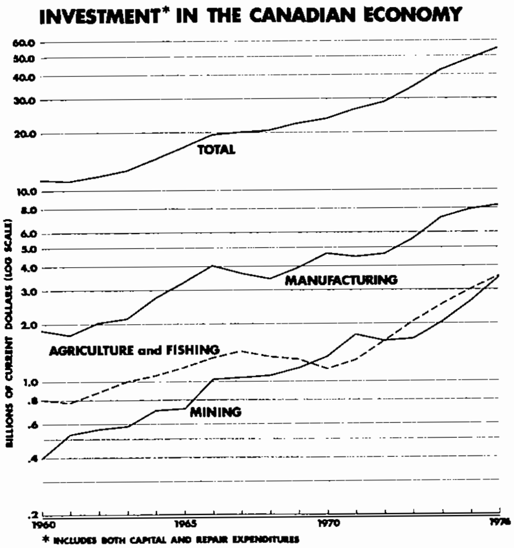


Figure 7

became negligible, or even negative. No other demand sector came forward to build on the previous recovery. Governments continued to exercise restraint in stimulating demand in view of the underlying rates of inflation. Business investment failed to accelerate at the traditional point in the recovery cycle. Economic growth for the OECD area in the second half of 1976 slowed to an annual rate of 3.2 per cent. The sharp rebound which would normally be expected in the first full year of recovery after a severe recession failed to materialize. Real growth for OECD countries averaged a disappointing 5 per cent in 1976. Among OECD countries, the recovery was uneven. The United States and Japan, Canada's two major trading partners, both experienced real GNP increases of about 6 per cent in 1976. The recovery of the European countries was slower, with growth rates averaging only 3.7 per cent.

Rates of inflation continued to ease throughout 1976. Consumer prices in the OECD area, after increasing 11.4 per cent on average in 1975, increased by 8.6 per cent in 1976, although there were still wide differences among the major countries. The inflation record was better than expected earlier in the year, in large part because of the decline in many food prices. Commodity prices around the world recovered briskly from the slump experienced in 1975, but did not maintain their momentum.

The modest nature of the economic recovery left substantial levels of excess capacity and high unemployment rates in virtually all countries. The international balance of payments continued to be affected by the impact of higher oil prices and the different rates of growth and inflation. Many countries began the current recovery with a large current account deficit, even though the OECD area as a whole was about in balance. Since then, the area's current account balance has turned increasingly to deficit.

The oil-exporting countries, in general, experienced large current account surpluses in 1976, although they were considerably reduced from the previous two years. Lower demand for oil and smaller increases in prices limited the growth of export earnings, while imports soared. The decreased surpluses represented partial completion of the transfer of real resources, necessitated by the precipitous climb of oil prices in late 1973.

By contrast, 1976 represented a disappointing year for most of the oil-deficient developing countries. Despite improved agricultural harvests, inflation remained high and their dependence on imported oil continued to be an intractable problem. The modest world economic recovery permitted some renewed growth in exports, and with continued severe restrictions on imports, the current account deficit of these countries improved to some extent in 1976. However, their increased indebtedness presents financial problems of grave international concern.

The year 1976 was especially active for the international community* to focus attention on issues related to trade and development, including the mineral resource sector. Much of the discussion was a carryover from previously established dialogue. The Multilateral Trade Negotiation (MTN) discussions took on an air of renewed vigour with the tabling of several tariff formulae; Canada continued to stress the need for sector negotiations to move forward concurrently with other negotiating techniques. Discussions on the North-South issues, in which the developing countries are demanding a "New International Economic Order" as the only acceptable means to narrow the economic and social gap between developed and developing countries, reached a new level of expression in the Conference on International Economic Cooperation (CIEC) and the Fourth United Nations Conference on Trade and Development (UNCTAD IV). New developments during the year concerning both developing country issues and broader trade matters were also evident in organizations such as the International Monetary Fund (IMF), Law of the Sea Conference, commodity agreements and producer associations.

Multilateral Trade Negotiations (MTN). The Tokyo Round of Multilateral Trade Negotiations, officially launched under the auspices of the General Agreement of Tariffs and Trade (GATT) in September 1973, has now undergone more than three years of

*Much of the information on international negotiations is drawn from "Canadian Non-fuel Minerals in the International Scene, and Foreign Policy", D.B. Fraser, C.J. Cajka, W.E. Koepke and G.J. Ninacs, *Canadian Mineral Survey 1976*, Department of Energy, Mines and Resources, Ottawa, pp 18 and 19.

preliminary bargaining in Geneva and is likely to continue into 1978. Given the broad goal of trade liberalization, negotiators are trying to eliminate tariffs at the lower end of the scale while reducing, by upwards of 60 per cent or more, tariffs at the upper end of the scale and seeking to dismantle an array of non-tariff barriers that constrain the flow of goods in international markets. The prospect of gaining free access to the United States, Japanese and EEC markets for smelted and refined metals and substantially reduced barriers for semi-fabricated and fabricated mineral and metal products is of particular interest to Canada. Accordingly, Canada has promoted a sector approach as a means of tackling both tariff and non-tariff barriers in a package that hopefully will contain rights and obligations to ensure that negotiated trade liberalization will not be impaired by other devices. Copper, nickel, lead and zinc are among those commodities being considered as candidates for the sector approach.

Conference on International Economic Co-operation (CIEC). The CIEC was originally perceived as a forum for international consultations with the oil-producing states on the global oil situation. This focus proved to be unacceptable to either the oil states or the developing countries in general, with the result that the inaugural Ministerial Meeting in December 1975 agreed to proceed with discussions on four broad fronts under tha auspices of separate commissions: Energy, Raw Materials, Finance and Development. The CIEC consists of 27 states — eight industrialized and 19 developing (including seven OPEC) countries. Each commission is made up of 10 developing and five industrialized countries. As well as co-chairing the conference with Venezuela, Canada is a member of the Energy and the Development commissions and is auditor on the other two.

The first half of 1976 was largely devoted to defining and elaborating the problems for consideration of the CIEC, whereas the second half was designated the action-oriented phase which was to conclude with ministerial agreement on commitments, recommendations and resolutions. By the end of the year it was clear that the developing countries were disenchanted with the progress made in the commissions and, with the risk of confrontation near-certain, developed and developing countries agreed to defer a concluding Ministerial Meeting from December until early 1977.

United Nations Conference on Trade and Development (UNCTAD). The Fourth Conference of UNCTAD was held in Nairobi during May 1976. While the Conference adopted 12 major resolutions, the resolution on an Integrated Programme for Commodities was of principal importance in the UNCTAD context as well as having major implications for the Canadian mineral industry. This resolution provides for a timetable of preparatory meetings on 18 commodities — including copper, iron ore, tin, bauxite, phosphate rock and manganese — and negotiating conferences for the purpose of concluding individual commodity agreements, to be completed by the end of 1978. Provisions envisaged for the agreements include international buffer stocks and national stocks as the principal measures to stabilize commodity prices wherever such stocks are considered practical and feasible.

The resolution also calls for preparatory and negotiating meetings on a Common Fund that would facilitate the financing of commodity stocks within the program and that could be used for "other" purposes, as yet only partially defined.

Canada participates in all the UNCTAD discussions with the view to finding the best solution for individual commodity problems and, in the case of the Common Fund, to determine whether such a fund would be effective and useful. Preliminary meetings on copper and the Common Fund were held late in 1976, with further meetings scheduled in 1977.

A subsidiary organ of UNCTAD, the Committee on Tungsten, held a meeting in November 1976. At issue in this forum is the question of whether the organization should institute a comprehensive system of studies and statistical publications, which could go a long way towards stabilizing the tungsten market, or whether to proceed directly with negotiations for a commodity agreement. The representatives of producing countries, frustrated by what they perceive as importer country foot-dragging, have requested the Secretary-General of UNCTAD to take action in regard to the convening of a negotiation conference on tungsten. Importing countries do not support the exporters' request and it remains to be seen how this discussion will proceed.

Other conferences and institutions. The Law of the Sea Conference ended the year's session in September. During the course of the negotiations, the United States put forth a proposal on production guidelines for seabed nickel that has major implications for the Canadian nickel industry in terms of future production levels. Attempts to have this Canadian concern reflected in an amendment to the United States proposal were still in motion at the close of the current series of meetings.

A decision within the International Monetary Fund (IMF) to dispose of 777 587 kilograms (kg) (25 million ounces) of gold was put into play early in 1976; sales in lots of 24 261 kg (780 000 ounces) were conducted at about six-week intervals. Profits from the sales are deposited in a separate trust fund for the use of developing countries. During the first half of the year, these sales had a depressing impact on the market, and the price of gold declined to levels where it was no longer profitable for many Canadian gold mines to continue operations. By the end of the year the price of gold had recovered, partly because of a change in the method of accepting bids for the IMF gold. These IMF gold sales are slated to continue at six-week intervals until the full stock is depleted.

The Fifth International Tin Agreement, negotiated in 1975, came into effect on July 1, 1976. As in the previous tin agreement, it has provisions for a 20 000-tonne buffer stock designed to stabilize tin prices and to be financed by producer countries. A new feature of the fifth agreement is a provision for voluntary contributions by consumers to finance an additional 20 000 tonnes of tin in the buffer stock. Canada, as well as being a signatory to the agreement, has undertaken to make such a voluntary contribution. The fifth agreement also marked another milestone, as it was the first time that the United States had joined.

Bilateral developments. Canada, in keeping with its "third" option on foreign policy, is embarking on new attempts to strengthen economic and commercial links with its Atlantic and Pacific trading partners. In June 1976, Canada and the EEC signed a Framework Agreement for commercial and economic cooperation, and in December set up a Joint Co-operation Committee that has the task of fulfilling the objectives of the agreement.

A somewhat similar agreement was signed with Japan in October. At this point in time it is difficult to predict just what impacts these new endeavours will have on the mineral industry; perhaps the first areas of co-operation will be in exploration and metallurgical research.

Mineral Industry

Mineral Production. In 1976 the total output of Canadian minerals, including metals, non-metals, structural materials and mineral fuels, reached a level of $15.4 billion, compared with $13.3 billion the previous year. In general, this reflected increases in both the quantities of the various commodities produced and in their prices.

The highest production value was in the mineral fuels sector, including coal, natural gas, natural gas byproducts and crude petroleum, which rose to $7.99 billion in 1976 from $6.65 billion in 1975. Alberta's output of fuels increased to $6.83 billion in 1976 from $5.57 billion in 1975.

Metal mining production had a value of $5.24 billion in 1976, up from $4.79 billion in 1975. Ontario was the leading province in metals output, with a production value of $2.15 billion, up from $1.95 billion in 1975.

In non-metals mining, production was $1.14 billion in 1976 compared with $0.94 billion in 1975. Leading minerals in the group were: asbestos, at $445.5 million in 1976, up from $267.2 million in 1975; and potash, at $361.4 million, up from $358.6 million in 1975.

The total value of structural materials was $1.02 billion in 1976, up from $0.96 billion in 1975. Leading materials were: cement, at $339.2 million, up from $320.2 million; sand and gravel, at $320.8 million, up from $305.2 million; and stone, at $209.6 million, up from $202.1 million in 1975.

Figure 8 illustrates growth of the three major sectors of the Canadian mineral industry between 1960 and 1976. The value of mineral production has grown at about 12.1 per cent a year during the period, with mineral fuels growing at a higher rate than metallic and industrial minerals. During 1976 the per capita value of mineral production went up by $80.69 to $666.08, while mineral production as a percentage of GNP rose from 8.07 to 8.10.

Figure 9 shows mineral production by commodity and by province for 1976 in percentage terms. As in the previous year, petroleum was the dominant mineral commodity in terms of value of output with 26.8 per cent of the total. In terms of provincial mineral production, Alberta made the largest single contribution, 45.4 per cent of the total, followed by Ontario, which contributed 16.9 per cent.

Mineral Prices. The prices of Canadian minerals are mainly determined in international markets. In general, mineral prices increased in 1976, but the growth varied considerable among commodities. For example, at year-end, the Canadian producer price* for copper

CANADA
VALUE OF MINERAL PRODUCTION

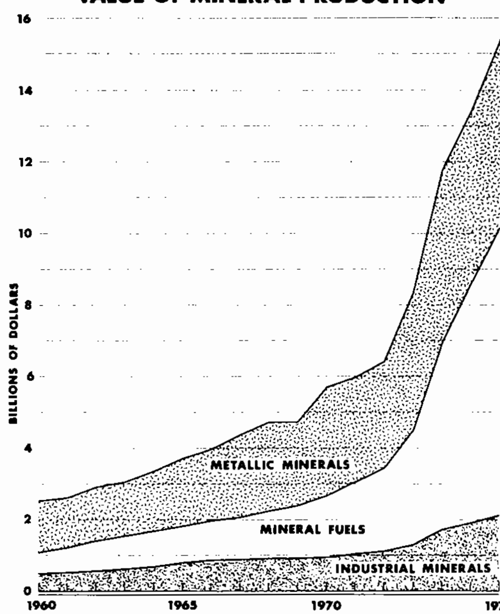


Figure 8

*Applicable to North American markets.

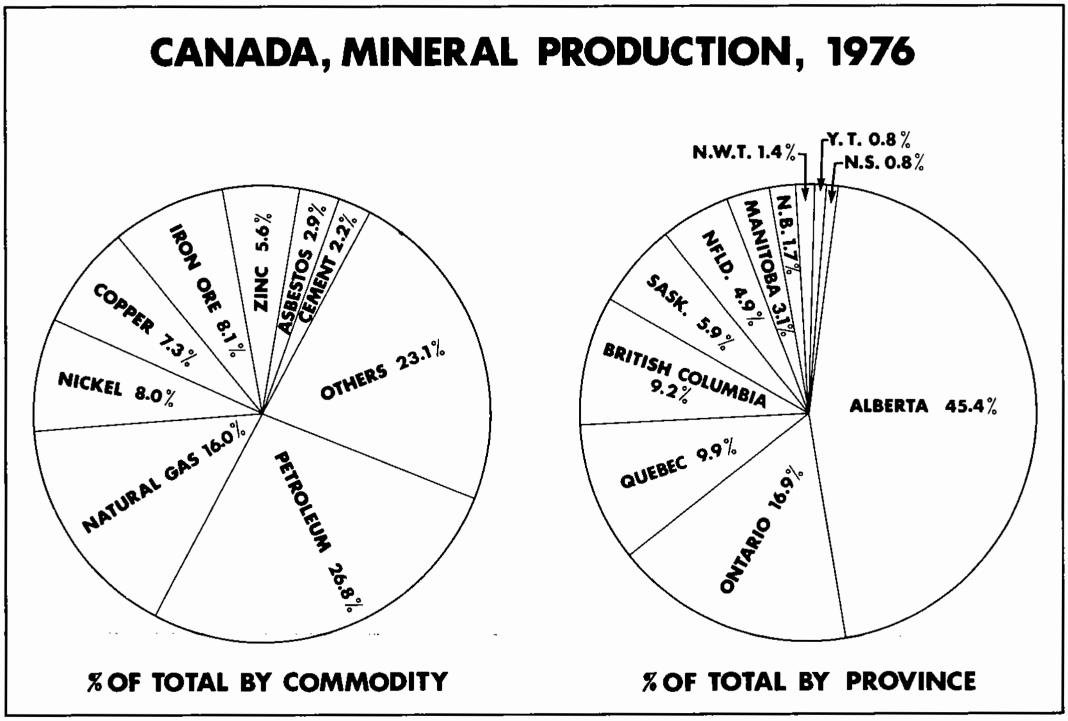


Figure 9

was 66.50 cents a pound, up from 63.38 cents at the end of 1975; nickel was $2.41 a pound, up from $2.20 a year earlier; iron ore was $20.51 a long ton compared with $18.75 in 1975. By contrast, the price of potash remained constant, and the price of zinc decreased to 36.25 cents a pound from 37.0 cents a year ago. The price of gold also decreased.

The trends in general wholesale price indexes of mineral products since 1951 are shown in Figure 10. The iron product index, which has been the highest mineral industry price index in recent years, reached 576.0 in December 1976. This was a 5.1 per cent increase over December 1975, compared with the nonferrous metal index, which went up 10.7 per cent; the nonmetallic minerals index, which rose 7.8 per cent and the general wholesale index, which rose 4.5 per cent.

Mineral trade. Canada exported $12.0 billion worth of crude and fabricated minerals during 1976, with the United States buying the bulk of mineral exports, 68.7 per cent, while Japan took 9.2 per cent, the United Kingdom 5.5 per cent, and the remainder of the European Economic Community (EEC) 7.6 per cent. Figure 11 illustrates the declining share of the value of mineral exports to the United Kingdom in the last decade and the fact that expotts to Japan and other countries have increased.

Trends in Canadian mineral trade since 1964 are given in Figure 12. The $12.0 billion in mineral exports

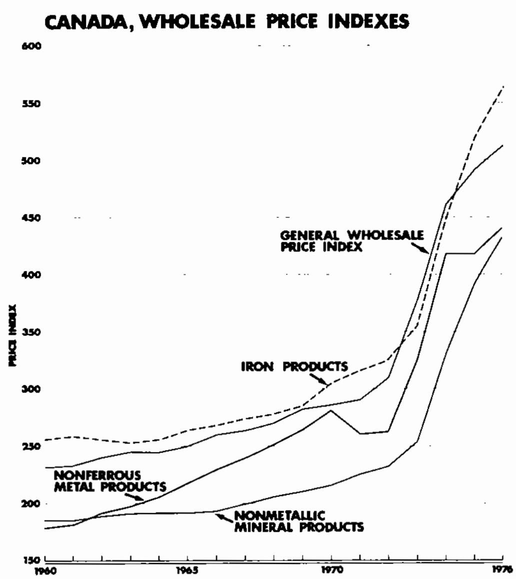


Figure 10

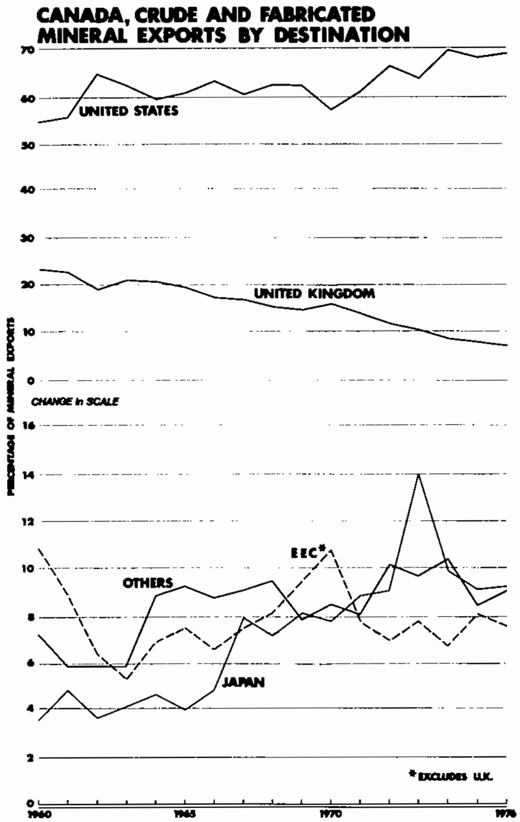


Figure 11

in 1976 was 7.2 per cent higher than the previous year. The share of mineral exports of crude and fabricated materials, as a percentage of total Canadian trade, decreased slightly in 1976 to 32.2 per cent from 34.7 per cent in 1975. During the period 1964-76, the share of exports of mineral fabricated products was running at an average of about 12.9 per cent, but this fell to 10.6 per cent during 1976, while crude minerals moved up from an average of about 18.4 per cent to 21.6 per cent.

Mineral investment. Trends in mineral investment in durable physical assets, including both capital and repair expenditures, for six major mineral sectors from 1960 to 1976, are illustrated in Figures 13 and 14. In mining, investment in mineral fuels in 1976 at $2.5 billion was 37.1 per cent higher than 1975, compared with nonmetal mines at $562.9 million, a rise of 6.1 per cent; and metal mines at $1.4 billion, an increase of 13.8 per cent. Similarly, in mineral manufacturing, investment in nonmetallics at $390.6 million was 6.9 per cent higher than 1975, compared with petroleum and coal products at $488.5 million, a fall of 16.3 per cent; and primary metals at $1 301.2 million, a fall of 9.9 per cent.

Return on invested capital. Figure 15 compares the average 1964-76 rate of return on invested capital* for various sectors in the Canadian mineral industry with the total of all Canadian industries. Among the sectors presented, petroleum products show the highest average rate of return at 14.0 per cent, primary metals the lowest at 9.7 per cent, compared with the total of all Canadian industries at 12.5 per cent. The relevant values in 1976 were in some cases higher, and in some cases lower, than the average values. The rate of return in metal mines for 1976 was 8.8 per cent, in mineral fuels, 20.0 per cent, and in all industries, 12.2 per cent.

In the mining industries** the rate of return in 1976 was 14.9 per cent. This is a relatively high rate compared to that of the past ten years when the highest level was achieved at 18.2 per cent in 1974 and the lowest at 7.1 per cent in 1972. In the mineral-based manufacturing industries*** the 1976 rate of return was 11.2 per cent. This rate is slightly below the average experienced over the last ten years, when it fluctuated between a low of 7.9 per cent in 1967 and a high of 18.2 per cent in 1974.

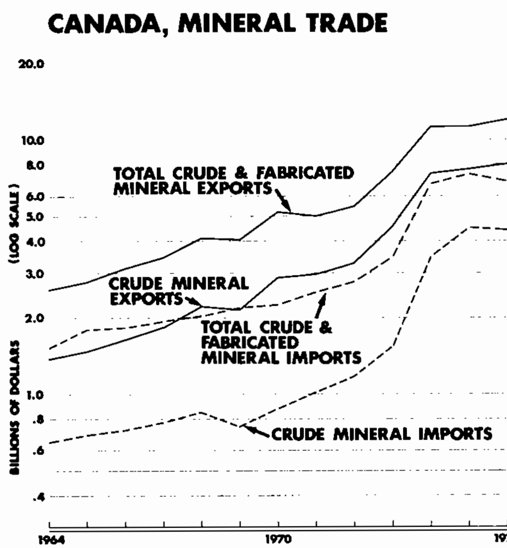
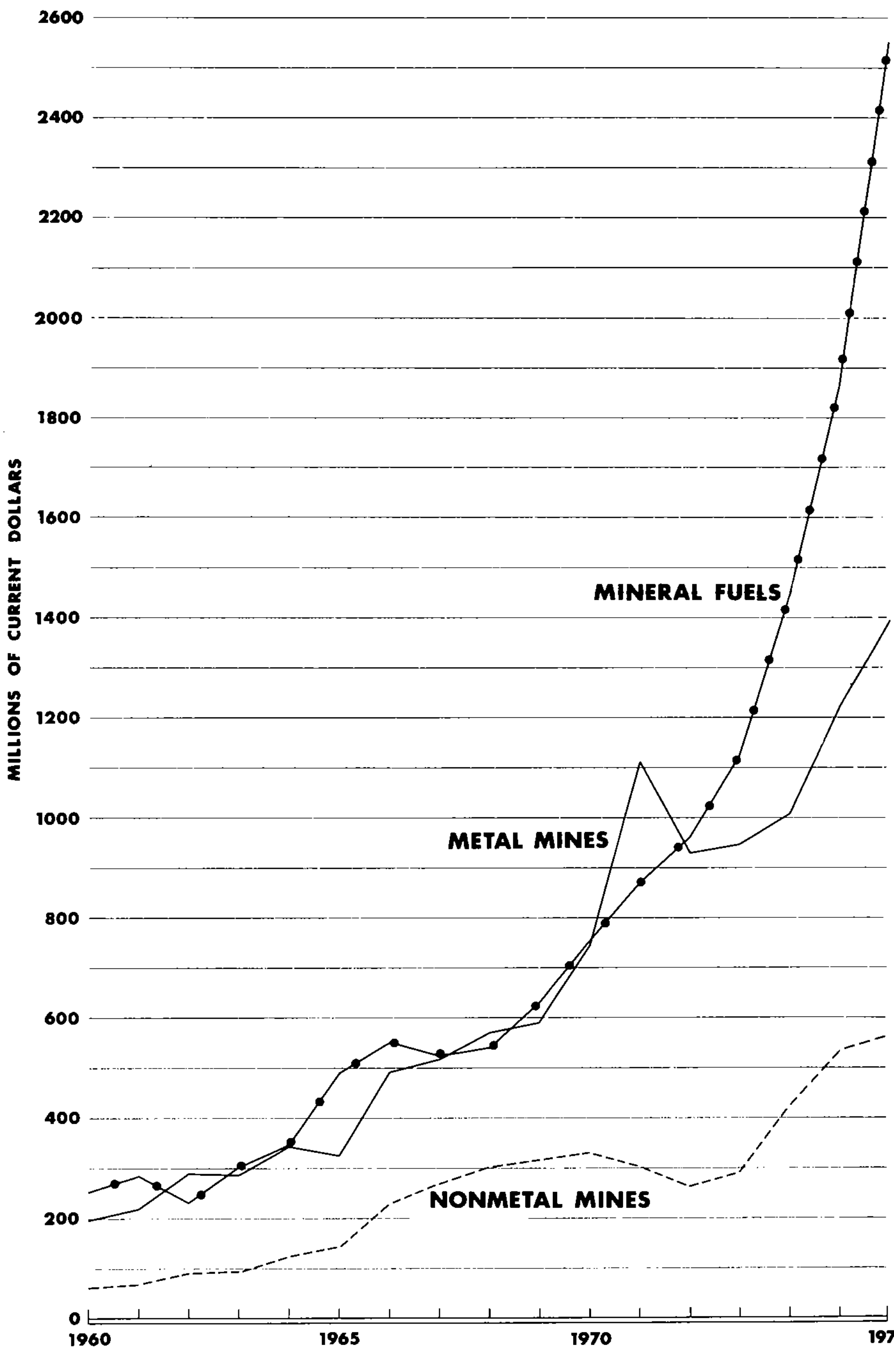


Figure 12

*Pre-tax profit (total assets minus total current liabilities) x 100.
**Includes metal mines, nonmetal mining and mineral fuels.
***Includes primary metals, nonmetallics, and petroleum and coal products.

CANADA, INVESTMENT* IN MINING BY SECTOR



* INCLUDES BOTH CAPITAL AND REPAIR EXPENDITURES

Figure 13

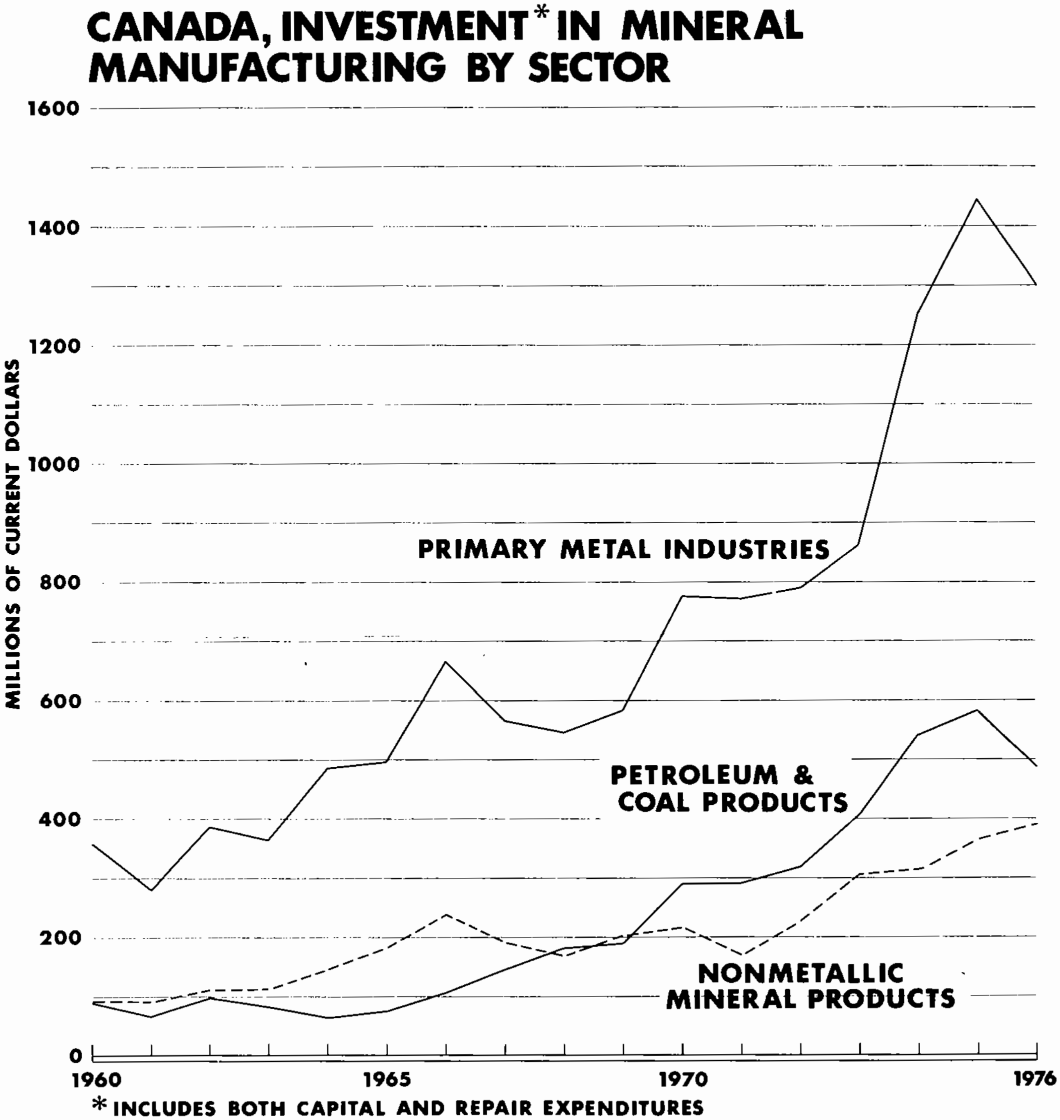


Figure 14

Outlook

The Canadian Economy. The outlook for Canadian economic activity appears to be relatively weak for 1977, and well below potential (5 per cent) growth. The slowdown in the recovery from the 1974-75 recession, which started for Canada and most other industrialized countries early in 1976, will in all probability continue during the forthcoming year. The federal government may provide some tax relief in the form of personal and/or corporate income tax costs during 1977, in order to give some impetus to growth. However, in general, the government can be expected to exercise fiscal and monetary restraint in stimulating the economy, in view of the underlying rate of inflation. Canada's real gross national product (GNP) is expected to grow at about 3.0 per cent in 1977.

The OECD countries, as a whole, are forecast to grow at a lacklustre 4 per cent in real GNP for 1977. Among OECD countries, Canada's principal trading partners, the United States and Japan, are expected to grow at a faster 5 to 5.5 per cent, whereas OECD

RETURN ON INVESTED CAPITAL AVERAGE 1966-1977

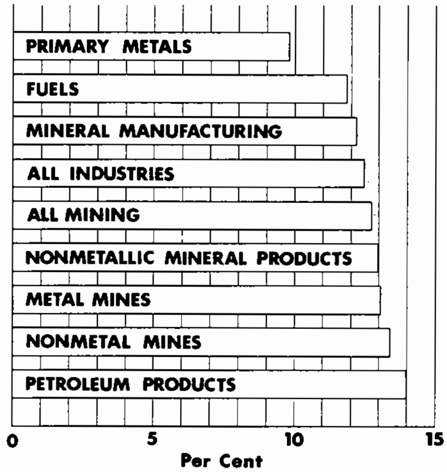


Figure 15

Europe will grow only about 2.75 per cent. Canadian exports to all areas should increase approximately 7 per cent in real terms in 1977. Imports will be limited by the poor performance of the domestic economy and should grow by 2 per cent in constant dollars. Although the balance on merchandise trade will remain positive and improve, nonmerchandise transactions are expected to go increasingly negative, with the result that the current account deficit will reach about 4.2 billion in 1977.

The slow growth of the domestic and foreign economies will continue to provide a dampening effect on the rate of inflation. Wage and price controls are expected to remain in force in Canada during the upcoming year. Inflation, as measured by the consumer price index, is forecast to improve by declining to about 8 per cent in 1977. On the other hand, unemployment is expected to worsen. The anticipated increase in employment will be more than offset by higher participation rates, and by the population bulge reaching working age. The unemployment rate should climb to about 8 per cent in 1977, the highest level since the 1930s.

Business capital spending will continue to be a drag on the economy during 1978. Profits often serve as the basis for future investment, and profit performance in the last year has been poor, in current dollars, and more so when adjusted for inflation. Industry continues to be plagued with low rates of capacity utilization. Uncertainty about the future has heightened; at the political level following the recent election in the Province of Quebec, with regard to taxation, regulations and controls by governments; and concerning the future of the domestic and foreign economies. In light of the above factors, business investment in plant and equipment can be expected to increase by a minimal 1 per cent in real terms in 1977.

Consumer spending should weaken in 1977, to about 2.8 per cent growth. Interest rates will remain high, about 9.5 per cent for long-term industrial bonds. High interest will be necessary to attract foreign capital in order to balance Canada's international payments and help finance government and capital expenditures. It is anticipated that housing starts will be down in 1977.

The longer-term outlook for Canadian economic activity indicates a gradually improving picture. Real GNP is forecast to grow at 4.0 per cent in 1978, accelerating to 5.0 per cent in 1979 and 1980. The forecast is based on the assumption that real GNP in the United States will grow at about 3.9 per cent in 1978 and 79, slowing to 2.2 per cent in 1980, and that the economies of OECD-Europe and Japan will grow at about 5 per cent and 6 per cent, respectively during the period. The domestic rate of inflation will gradually improve, declining to about 5.5 per cent in 1980. Unemployment will continue to remain at unusually high levels, perhaps slackening to 7.5 per cent by 1980. Consumer spending and business investment will improve. Interest rates will remain high, by historical standards, in the order of 10 to 11 per cent for long-term industrial bonds. Corporate profits can be expected to increase. The merchandise trade balance will remain positive and the current account balance will continue in deficit during the period.

The mineral industry. The mineral industry accounts for about one-third of all Canadian exports, contributes to the prosperity of all Canadians, and is crucial to the nation's international trade balance. Canada is endowed with considerable mineral resource wealth, but in recent years, the industry has experienced a number of problems. The prices and demand for a number of the major commodities have fallen to depressed levels. The federal and provincial governments have introduced numerous changes in legislation and taxation. Foreign competition from new mineral suppliers has increased. Capital and operating costs have climbed.

The short-term prospects for certain parts of the industry — gypsum, potash, asbestos, lead, uranium, molybdenum and gold — range from fair to excellent. For the base metal and ferrous sector, the outlook has become more encouraging. The world demand and prices for copper, zinc and aluminum are expected to strengthen sometime before 1981. Most other prices will at least keep pace with inflation. The federal and provincial governments can be expected to work towards nationalization of legislation and taxation affecting the mineral industry.

Canada will face increased world competition as a major mineral supplier due to possible supply-demand imbalances and new mineral discoveries and developments in many parts of the world. For example, iron ore is being increasingly supplied from Brazil and Australia, copper from Africa and the Pacific rim countries, nickel from Guatemala, Australia, Indonesia and New Caledonia, and uranium from Australia and southern Africa. Canada will have to continue its efforts in future years to sustain existing markets and to develop new markets for our products.

Regional Review

THOMAS W. VERITY

Federal-provincial mineral development programs

General Development Agreements (GDA's) between the federal government and all the provinces, except Prince Edward Island, were signed in 1974 and Mineral Development Agreements (MDA's) subsequent to 1974 were subsidiary to the GDA's. The Department of Regional Economic Expansion (DREE) and the Department of Energy, Mines and Resources (EMR) represent the federal interest in the MDA's. Results of the joint programs are available to the public and provide an incentive for private sector exploration and development.

Development Agreements were in effect in 1976 between the federal government and the provinces of Newfoundland, Nova Scotia, New Brunswick, Quebec, Manitoba and Saskatchewan.

Shared-cost Uranium Reconnaissance Programs (URP's) were underway between the Geological Survey of Canada (GSC) which is a part of EMR and the provinces of New Brunswick, Ontario, Saskatchewan and British Columbia.

Newfoundland. This province had an early start on a federal-provincial mineral program with the signing on September 3, 1971 of the Canada-Newfoundland Mineral Exploration and Evaluation Agreement. The cost of this $2.7 million program was borne entirely by the federal government. The cost was shared equally between DREE and EMR. This agreement terminated on March 31, 1976. The program included a mineral inventory, mineral development planning studies, evaluation of selected minerals and areas and regional geochemical reconnaissance surveys. The program led to changes in provincial mineral land tenure and taxation policies, and geoscientific projects resulted in reports and maps useful to mineral exploration companies. The program helped the Newfoundland Department of Mines broaden and improve its geoscientific capabilities.

A new five-year Subsidiary Agreement on Mineral Development, between Canada and Newfoundland, was signed on December 17, 1976. It will begin on January 1, 1977 and terminate on December 31, 1981. The estimated cost is $12,458,000 with 90 per cent being funded by Canada through equal sharing by DREE and EMR. The program will consist of four major projects; regional mineral potential evaluation, mineral development strategies, mineral resources management and program evaluation.

Nova Scotia. A Subsidiary Agreement on Mineral Development was signed on February 17, 1975, to remain effective until March 31, 1979. Estimated cost of the program was $6,338,000, with DREE providing 80 per cent and the province 20 per cent. The projects included in the original agreement were: resource development planning, a mineral resource inventory, mineral evaluation surveys, geological-geochemical surveys, laboratory services and program management and administration.

One of the mineral evaluation surveys was a coal inventory. Towards the end of the 1976-77 fiscal year, uncommitted funds in other projects were transferred to the coal inventory survey and the federal Treasury Board was asked to approve an additional $800,000 for the Sub-Agreement, mainly for coal drilling onshore, and also $5.2 million for drilling offshore in the Sydney coal basin. The coal inventory led to significant activities. The Nova Scotia Department of Mines advertised, in September 1976, that results to date would be put on open file and that proposals for the development of coal mines in the province were invited. Many companies responded, and several proposals were received. These proposals were being considered by the provincial Department of Mines at year end.

Prince Edward Island. There are no mineral development agreements with this province. The Island is unique in that, instead of a General Development Agreement it has had, since March 7, 1969, a 15-year Comprehensive Development Plan under the Fund for Rural Economic Development (FRED) legislation. Phase I of the Plan ended on March 31, 1975 and involved highway construction, improved education facilities and socio-economic development. Phase II, from April 1, 1975 to March 31, 1980, was signed on October 23, 1975 and DREE funding was to be up to $70 million. The province's share was $32,650,000, including a $9 million loan through EMR for the construction of a power cable, under Northumberland

Strait, to connect with the New Brunswick electric power grid on the mainland.

New Brunswick. This province had one of the first mineral agreements, the Canada-New Brunswick Accelerated Mineral Reconnaissance Agreement, signed on August 31, 1970. The program involved detailed geological mapping in the northern third and southern third of the province, an evaluation of industrial mineral deposits in the south, geochemical surveys, studies of possible improvements in the processing of base metals and resource planning and promotion. The agreement was extended past its original three-year term and expired on September 20, 1976. Cost of the program was $3,863,550 with DREE funding $3,728,550. Geological reports and maps, resulting from the program, were useful to industry in the selection of mineral exploration targets. The industrial mineral project resulted in the discovery of potentially important deposits of potash and salt in the Sussex and Salt Springs areas and the finding of new sand-gravel sources north of Moncton.

A new Subsidiary Agreement for Minerals and Fuels was signed in mid-1976 and will run until March 31, 1981 at an estimated cost of $11,313,000, with DREE funding 80 per cent and New Brunswick 20 per cent. The new agreement covered a wide variety of projects under two major programs. Program I, entitled Opportunity Identification, involved surveys of: coal resources, uranium (partly in conjunction with the URP program of the GSC), industrial and structural materials, mineral potential under Fundy National Park and detailed geological mapping of west-central New Brunswick. Program 2, entitled Opportunity Development, involved technical studies to; improve the recovery of base metals from mining operations in northeastern New Brunswick, reduce the sulphur content of coal, and a zinc reduction plant. Also included were studies of manpower problems in the mining industry, promotion of interest in prospecting and assistance to build resource roads to potentially important mining areas.

Quebec. Two mineral development programs were carried out in the Lac St. Jean-Saguenay-Chibougamau area and in northwestern Quebec, starting in 1971, and were funded under the Agricultural and Rural Development Act (ARDA). They consisted of access road construction, geoscientific surveys, geological mapping and research and metallurgical research. These programs ended in 1976 and cost a combined total of $6 million, funded equally by DREE and Quebec.

A similar mineral development program, also started in 1971, was carried out in eastern Quebec under the Fund for Rural Economic Development (FRED) and this also ended in 1976. The program cost $11,333,000 and was funded 75 per cent by DREE and 25 per cent by Quebec. Most of the activity was centred in the Gaspé peninsula but some attention was given to salt deposits on Îles-de-la-Madeleine in the Gulf of St. Lawrence.

A Subsidiary Agreement was signed on March 15, 1974, to continue until March 31, 1978, to assist Sidérurgie du Québec (SIDBEC), a provincial Crown corporation, in a major expansion of steelmaking capacity, modernization of some operations and the addition of a galvanizing capability. DREE's share in the cost was to be $30 million.

A new Canada-Quebec Mineral Development Subsidiary Agreement was signed on March 29, 1976. It will run for four years at a cost of $28.6 million, with DREE's share being 60 per cent and Quebec's 40 per cent. EMR will participate in the management committee with DREE and provincial representatives. Main components of the program were: construction of access roads in NW Quebec and Saguenay-Lac St. Jean; geological mapping in NW Quebec and Gaspé; geoscientific surveys in NW Quebec, Saguenay-Lac St. Jean, Gaspé, Anticosti Island and Grenville geological province; petroleum exploration and geoscientific surveys in St. Lawrence lowlands, Gaspé and Anticosti Island; construction of diamond drill core storage facilities; a deep drilling incentive program and research and development into mining technology problems.

Ontario. No direct mineral development agreements have been signed in Ontario, but socio-economic development agreements have been signed in northern and eastern Ontario that have some influence on mining communities and potential mining areas.

A Subsidiary Agreement on Northwestern Ontario was signed on May 23, 1974 and will run to March 31, 1978. Part of the agreement involved a community infrastructure program in the potentially important iron ore region around Lake St. Joseph and road improvements to the Pickle Lake area. DREE will provide half the cost of this agreement, estimated at $47,344,000.

A Subsidiary Agreement on Northeastern Ontario was signed on March 25, 1976 and will expire on September 30, 1979. The Sudbury and Parry Sound areas were identified for projects such as industrial park development, access roads construction and water and sewer systems. DREE will provide 50 per cent of the agreement cost, estimated to be $5,754,000.

Manitoba. A Subsidiary Agreement on Mineral Exploration and Development was signed on March 31, 1976 to extend to March 31, 1979. Total commitments under the agreement were $8.5 million, to be shared 20 per cent by DREE, 30 per cent by EMR and 50 per cent by Manitoba. The program involved the following projects: base metal exploration; a URP program, implemented by GSC; a regional survey and evaluation of geological data; an industrial mineral assessment; a pegmatite exploration survey of uncommon minerals and mineral development analysis and planning.

Results of the first season's work on the uranium reconnaissance project (already underway before the signing of the Agreement) was released March 24, 1976. This resulted in a minor staking rush into northwestern Manitoba. Publication of results of airborne geophysical surveys in the Lynn Lake area also resulted in the staking of more than 20 000 acres (8 094 hectares) for base metals by the private sector.

Saskatchewan. A Subsidiary Agreement on Mineral Exploration and Development for northern Saskatchewan was signed June 21, 1974 to expire on March 31, 1978. Cost of the program was to be $4,350,000 funded 25 per cent by DREE, 25 per cent by EMR and 50 per cent by Saskatchewan. Major elements of the agreement were: regional mineral resource planning; La Ronge-Wollaston base metal exploration; iron ore exploration; uranium exploration (with GSC); industrial minerals exploration and reconnaissance geoscientific surveys (at half the total cost).

Alberta. No direct MDA has been signed in this province but a subsidiary Agreement on Northland Development was signed March 11, 1975 to expire March 31, 1977. Cost of this program was to be $14,423,700 with DREE funding 50 per cent.

A three-year program of metallurgical research was started in 1974, funded jointly by the Alberta government and EMR, with research being undertaken on the mineralogy, beneficiation and reduction possibilities of the Clear Hills iron-bearing deposits. Tests were carried out by the Alberta Research Council in Edmonton and by the Canada Centre for Mining and Energy Technology (CANMET) of EMR in Ottawa. Results of the project were interesting from a scientific viewpoint but have revealed that the Peace River deposits would be uneconomic to mine for the foreseeable future.

British Columbia. No general MDA's have been signed in this province, but a Subsidiary Agreement for Western Northlands Highways in northern British Columbia was signed for the 1974-75 and 1975-76 fiscal years. The federal share of these projects was $5 million, shared equally between DREE and the Department of Transport (DOT).

During 1975-76 proposals were being drafted by the province for consideration by DREE and EMR that would involve sub-agreements on coal exploration and development in Northeast British Columbia and mineral evaluation studies in Northwest British Columbia. A coal agreement was signed in January 1976, which related to Northwest British Columbia. The agreement provided, through a Coal Planning Sub-Agreement, for the expenditure of $10 million for further evaluation of coal deposits and for field and preliminary infrastructure design studies and work.

Provincial mineral developments

The User Advisory Services Division of Statistics Canada (StatsCan) gathers data concerning Gross Provincial Products (GPP) supplied by the provinces. The sum of the GPP's approximately equal the Gross National Product (GNP) and GPP totals are being used in our provincial analyses and compared to the GNP.

Reference is made to the gross value of mineral production as a percentage of GPP. This comparison is not entirely valid since GPP and GNP totals are essentially the sum of "census values added" from

(text continued on page 20)

Table 1. Contribution by provinces and territories to Canada's total value of mineral production, selected years, 1960-1976

	1960	1965	1970	1975	1976p
			(per cent)		
Alberta	15.9	20.5	24.4	43.1	45.4
Ontario	39.4	26.8	27.8	17.6	16.9
Quebec	17.9	19.3	14.0	9.3	9.9
British Columbia	7.5	7.5	8.6	9.7	9.2
Saskatchewan	8.5	8.8	6.6	6.5	5.9
Newfoundland	3.5	5.6	6.2	4.1	4.9
Manitoba	2.4	4.9	5.8	4.0	3.1
New Brunswick	0.7	2.2	1.8	1.7	1.7
Northwest Territories	1.1	2.1	2.4	1.5	1.4
Yukon	0.5	0.4	1.4	1.7	0.8
Nova Scotia	2.6	1.9	1.0	0.8	0.8
Prince Edward Island	0.02	0.02	0.02	0.01	0.01
Total Canada, per cent	100.0	100.0	100.0	100.0	100.0
$ Millions	2 492.7	3 714.9	5 722.1	13 346.7	15 392.8

p Preliminary.

Table 2. Value of leading minerals by provinces and territories in 1976, and percentage change from 1975

	% of Total	% Change from 1975
British Columbia		
Copper	29.0	+13.5
Coal	21.6	−10.4
Natural gas	9.2	+68.3
Petroleum, crude	8.0	+20.4
Zinc	6.6	+14.0
Molybdenum	6.3	+24.9
Lead	3.1	+40.3
Sand and gravel	3.0	+2.1
Cement	2.7	+10.6
Silver	2.5	+23.2
Asbestos	2.2	−18.9
Gold	1.5	−14.8
Iron ore	0.6	−41.5
Metallics	50.0	+14.2
Nonmetallics	3.2	−18.0
Fuels	39.9	+7.0
Structural materials	6.9	+2.8
Total	100.0	+9.6
Yukon Territory		
Zinc	32.7	−55.0
Asbestos	26.3	−65.2
Lead	14.6	+5.0
Copper	12.7	+39.5
Silver	10.3	−52.9
Gold	3.0	−25.6
Metallics	73.2	−51.0
Nonmetallics	26.3	+5.0
Fuels	0.5	−54.2
Structural materials	—	—
Total	100.0	−43.1
Northwest Territories		
Zinc	56.1	+12.0
Lead	12.6	−28.0
Gold	10.8	−19.6
Natural gas	9.2	−0.8
Silver	7.0	+67.6
Petroleum, crude	3.9	+84.4
Copper	0.3	+25.3
Metallics	86.9	+1.7
Nonmetallics	—	—
Fuels	13.1	+15.1
Structural materials	—	—
Total	100.0	+3.3
Alberta		
Petroleum, crude	50.5	+9.6
Natural gas	32.9	+63.8

	% of Total	% Change from 1975
Natural gas byproduct	11.4	+1.4
Coal	3.2	+22.3
Elemental sulphur	1.0	−31.4
Sand and gravel	0.6	+24.0
Metallics	—	—
Nonmetallics	1.1	−27.6
Fuels	97.6	+22.6
Structural materials	1.3	+21.9
Total	100.0	+21.7
Saskatchewan		
Petroleum, crude	48.0	+7.0
Potash	39.8	+0.8
Sodium sulphate	2.4	+15.8
Cement	1.7	+53.9
Copper	1.6	+30.2
Coal	1.4	+33.9
Sand and gravel	1.1	−4.4
Natural gas	0.9	−21.0
Salt	0.9	+4.3
Natural gas byproducts	0.6	−9.3
Metallics	2.8	+34.9
Nonmetallics	43.2	+1.7
Fuels	50.9	+6.7
Structural materials	3.1	+24.4
Total	100.0	+5.4
Manitoba		
Nickel	50.0	−17.6
Copper	17.9	−5.7
Zinc	10.7	−3.0
Petroleum, crude	6.9	+4.9
Sand and gravel	5.2	+9.9
Cement	4.7	+32.5
Gold	1.2	−28.0
Silver	0.8	−15.4
Cobalt	0.4	−7.9
Stone	0.3	−6.8
Metallics	81.0	−13.6
Nonmetallics	0.9	−9.1
Fuels	6.9	+4.9
Structural materials	11.2	+18.1
Total	100.0	−9.7
Ontario		
Nickel	38.3	+22.5
Copper	15.0	+8.0
Zinc	10.2	−4.4
Iron ore	10.2	+20.6

Table 2. (cont'd)

	% of Total	% Change from 1975
Ontario (concl'd)		
Cement	4.5	+4.9
Sand and gravel	3.7	−0.4
Gold	3.5	−26.9
Silver	2.6	−0.3
Stone	2.6	+6.8
Clay	2.0	+13.8
Platinum	1.9	−13.6
Salt	1.7	+37.2
Metallics	83.0	+10.5
Nonmetallics	2.9	+34.8
Fuels	0.5	+2.0
Structural materials	13.6	+5.9
Total	100.0	+10.4
Quebec		
Asbestos	22.6	+93.9
Iron ore	21.3	+50.9
Copper	11.9	+9.9
Zinc	7.7	+6.0
Stone	6.7	−1.5
Cement	5.8	−12.8
Sand and gravel	5.0	+7.7
Titanium dioxide	4.9	+33.3
Iron remelt	4.3	−19.4
Gold	3.8	−21.6
Lime	1.4	+8.2
Silver	1.0	+3.2
Metallics	50.3	+14.6
Nonmetallics	28.9	+73.3
Fuels	—	−75.0
Structural materials	20.8	−0.5
Total	100.0	+22.7
New Brunswick		
Zinc	55.8	+15.5
Lead	12.1	+16.7
Silver	8.4	−5.5
Copper	5.7	−7.4
Stone	2.7	−15.1
Coal	2.5	−11.3
Sand and gravel	1.6	−3.3
Metallics	85.4	+10.5
Nonmetallics	2.7	+8.1
Fuels	2.5	−11.4
Structural materials	9.4	+14.5
Total	100.0	+10.1
Nova Scotia		
Coal	46.5	+22.2
Salt	15.0	+21.5
Sand and gravel	12.3	+2.5
Gypsum	11.3	+7.8
Cement	6.0	+15.8
Stone	3.8	−5.1
Clay	3.3	+24.1
Barite	0.6	−19.3
Peat	0.4	+0.9
Metallics	—	—
Nonmetallics	28.1	+14.0
Fuels	46.5	+22.2
Structural materials	25.4	+6.6
Total	100.0	+15.6
Prince Edward Island		
Sand and gravel	100.0	−4.9
Structural materials	100.0	−4.9
Total	100.0	−4.9
Newfoundland		
Iron ore	85.1	+37.3
Zinc	5.0	+42.1
Asbestos	4.4	+84.0
Copper	1.3	−3.3
Sand and gravel	1.2	−4.0
Cement	0.7	+7.2
Lead	0.6	+98.2
Fluorspar	0.3	—
Metallics	92.6	+36.6
Nonmetallics	5.1	+84.2
Fuels	—	—
Structural materials	2.3	−1.3
Total	100.0	+37.2
Canada		
Petroleum, crude	26.8	+9.7
Natural gas	16.0	+62.2
Iron ore	8.1	+35.2
Nickel	8.0	+12.0
Copper	7.3	+9.3
Zinc	5.6	−1.2
Natural gas byproducts	5.2	+1.5
Coal	3.9	+3.0
Asbestos	2.9	+66.7
Potash	2.4	+0.8
Cement	2.2	+5.9
Sand and gravel	2.1	+5.1
Stone	1.4	+3.7
Gold	1.3	−23.3
Silver	1.1	−2.1
Lead	0.8	−17.0
Metallics	34.1	+9.3

Table 2. (concl'd)

	% of Total	% Change from 1975
Canada (concl'd)		
Nonmetallics	7.4	−21.7
Fuels	51.9	+20.1
Structural materials	6.6	+5.8
Total	100.0	+15.3

Source: Statistics Canada.
— Nil.

goods-producing and other industries rather than the "gross" values obtained from industrial and other production. However, StatsCan census value added data are only available up to the year 1974 and the gross value of mineral production is being used in our provincial analyses for the years 1975 and 1976.

In the census value added analyses for 1974, primary production includes agriculture, forestry, fisheries, trapping, mining and electric power; secondary production includes manufacturing and construction; and services include all other activities, e.g., utilities, trade, finance, business, personal services and public administration. Census value added for mining is the gross value of production less the cost of fuel, electricity, process supplies, containers, freight and treatment charges.

Statistical tables show the gross value of provincial mineral production, on a percentage basis, for selected years between 1960 and 1976 and also the value of leading minerals in each province and territory, on a percentage basis, together with the per cent change from 1975.

Statistical information on exploration and development expenditures for mining operations in the provinces for 1975 and 1977 is summarized in Figure 1.

British Columbia. 1975: GPP = $18.36 billion (a 13.5 per cent increase from 1974 and 11.4 per cent of the GNP). Mining (gross value) = $1.30 billion (7.1 per cent of the GPP and 9.1 per cent of Canada's mineral production value).

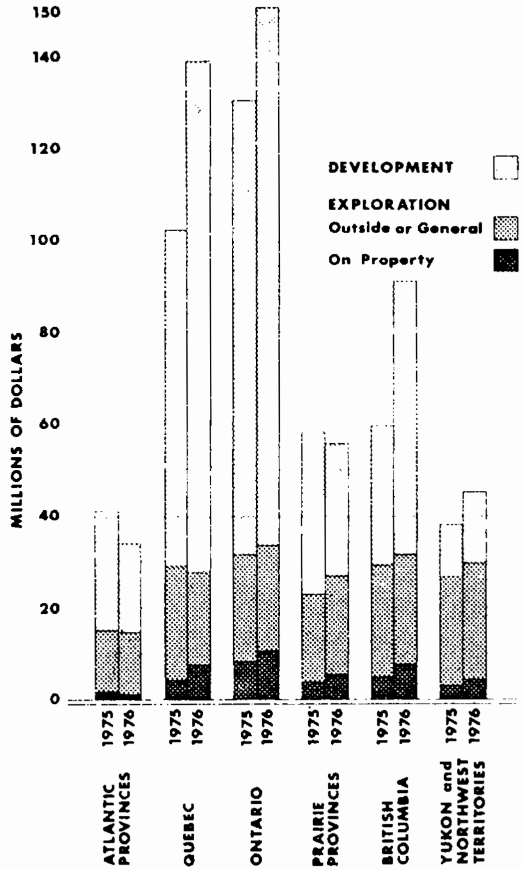
1976: Mining (gross value) = $1.42 billion (+9.6 per cent and 9.2 per cent of Canada's mineral production). Participation rate in the labour force was 61.5 per cent. Unemployment was 8.6 per cent (yearly average).

The British Columbia economy (as indicated by 1974 census values added) showed primary production 12.4, (mining 4.9, forestry 3.6), secondary 30.4 and services 57.2 per cent of the GPP.

The Price Waterhouse & Company report on the British Columbia mining industry, commissioned by the Mining Association of British Columbia, reported that the industry hit bottom in 1974-75. The copper

EXPLORATION and DEVELOPMENT EXPENDITURES*

1975 Final & 1976 Preliminary



*Excludes expenditures for oil and natural gas
Source: Statistics Canada

Figure 1

industry showed signs of revival in 1976, and coal should become the main source of revenue with a good potential for future development.

The provincial government has removed or changed some of the more onerous tax provisions for mining and this has resulted in increased interest in mineral development projects.

Yukon Territory. 1975: Mining: $230 million (1.7 per cent of Canadian mining).

1976: Mining: $131 million (0.8 per cent of Canadian mining).

Statistics Canada does not produce GPP figures for the Yukon Territory and the Northwest Territories but census value added figures (1974) show primary production of 99 per cent and manufacturing 1 per cent for the combined territories.

Mineral production value in the Yukon Territory reached an all-time high in 1975, but declined by 43 per cent in 1976, due mainly to labour disputes at base metal mines in the Whitehorse, Elsa and Faro areas. Evaluation of the Grum joint venture base metal prospect near Faro was completed in 1976 and the data collected will be summarized during 1977. Exploration activity was less than in 1975, but more claims were staked and assessment work was higher.

Northwest Territories. 1975: Mining: $206 million (1.5 per cent of Canadian mining).

1976: Mining: $213 million (1.4 per cent of Canadian mining).

Mineral production in the Northwest Territories reached a record value in 1974, but declined by 7.5 per cent in 1975 and rose by 3.3 per cent in 1976. Zinc, lead and gold were the principal minerals. Exploration activities were greatly reduced during 1976. The chief areas of activity were Baker Lake, Izok Lake, Redstone River and the Pine Point area.

The major event of concern to the mining industry during 1976 was the announcement by the Inuit Tapirisat of Canada of their land claims in the Arctic. While no negotiations have been undertaken with the federal government, the Inuit have aroused considerable public support. Wide ranging proposals for Inuit participation in northern development will require much co-operation and understanding if the issues are to be resolved satisfactorily.

In the Arctic Islands, Nanisivik Mines Limited commenced production at its Zn-Pb-Ag mine at Strathcona Sound on Baffin Island late in 1976 but Arvik Mines Ltd. delayed plans to develop the Polaris Pb-Zn mine on Little Cornwallis Island. Large scale exploration for oil and natural gas started in the Mackenzie Delta area in 1965. Some 116 exploratory wells have been drilled in the Mackenzie River Delta-Beaufort Sea region and 107 wells in the Sverdrup Basin area of the Arctic Islands.

Alberta. 1975: GPP = $15.5 billion (18.5 per cent increase and 9.6 per cent of the GNP). Mining = $5.75 billion (37.1 per cent of the GPP and 43.1 per cent of Canadian mineral production).

1976: Mining = $7.0 billion (+21.7 per cent and 45.4 per cent of Canadian mineral production).

Participation rate in the labour force was 66.5 per cent and unemployment 3.9 per cent.

Census values added (1974), showed a high primary production of 43.5 per cent (mining 32.1, agriculture 9.8) with a secondary production of 21.4 and services 35.1 per cent of the GPP.

Alberta has been the leading province in value of mineral production since 1971, due primarily to its production of crude petroleum, natural gas and natural gas byproducts. The value of these minerals increased rapidly in recent years due mainly to increased prices rather than increases in the volume of production.

On June 21, 1976 the government of Alberta published a brochure entitled *A Coal Development Policy for Alberta.* The policies expressed contained some restrictive features that coal operators say will be a deterrent to exploration for development of coal. Metallurgical studies continued during the year on the Peace River iron ores deposits. Technical studies were made on a red granite deposit at Fort Chipewyan. Uranium exploration was undertaken in the province's northeastern corner but no encouraging results have been announced. Construction of a large scale ethylene plant will commence at Red Deer in 1977. The plant will have an ethylene capacity of 545 000 tonnes a year.

Saskatchewan: 1975: GPP = $6.15 billion (10.7 per cent increase and 3.8 per cent of the GNP). Mining = $862 million (14.0 per cent of the GPP and 6.5 per cent of Canadian mineral production).

1976: Mining = $909 million (+5.4 per cent and 5.9 per cent of Canadian production).

The labour participation rate was 60.4 per cent and unemployment 4.0 per cent.

Census values added (1974) showed the highest primary production of any province with 45.8 per cent of the GPP (agriculture 32.9, mining 11.1). Secondary production was 12.8 and services 41.4 per cent.

Major minerals were crude petroleum and potash. The province also produced about 14 per cent of Canadian uranium output, but uranium values are not included in Statistics Canada mineral production estimates for Saskatchewan or for Canada.

The Saskatchewan government announced changes during 1976 to the Minerals Resources Act that included new petroleum and natural gas regulations and a new royalty tax on uranium. The Potash Corporation of Saskatchewan was established by Act of Parliament in 1975. This corporation can own and operate potash mines, sell potash and enter into joint ventures with private potash companies. The Potash Development Act, 1974, empowered the Corporation to purchase the assets of potash companies. The Duval Corporation of Canada was purchased in 1976 and the purchase of two other companies was under consideration. The provincial government recently released a publication entitled *An Industrial Development Strategy for Saskatchewan.* Included was the proposed construction of a large fully developed iron and steel complex which was one of the objectives of the Canada-Saskatchewan Iron and Steel Agreement signed in July 1974.

Manitoba. 1975: GPP = $6.7 billion (10.8 per cent increase and 4.2 per cent of the GNP). Mining = $530 million (7.9 per cent of the GPP and 4.0 per cent of Canadian production).

1976: Mining = $478 million (−9.7 per cent and 3.1 per cent of Canadian mineral production).

The labour participation rate was 64.0 per cent and unemployment 4.7 per cent. Census values added

(1974) showed a primary production of 16.8 per cent (mining 4.6) with a secondary production of 22.2 and a high service sector of 61.0 per cent of the GPP.

Major minerals were nickel, copper and zinc with metallic minerals totalling about 81 per cent of the mineral production. Principal mineral producing areas were Thompson, Snow Lake, Flin Flon and Lynn Lake in the northwestern part of the province and, at Bernic Lake, the Tantalum Mining Corporation of Canada Limited, a tantalum and cesium producing mine.

Ontario. 1975: GPP = $64.0 billion (9.8 per cent increase and 39.7 per cent of the GNP). Mining = $2.35 billion (3.7 per cent of the GPP and 17.6 per cent of Canadian mineral production).

1976: Mining = $2.59 billion (+10.4 per cent and 16.9 per cent of Canadian mineral production).

The labour participation rate was 64.0 per cent and unemployment 6.2 per cent.

Ontario was the highest contributor to the GNP of any of the provinces and census values added (1974) indicated it to be the most highly industrialized of any of the provinces. Primary production was only 6.7 (mining 2.8, agriculture 1.8) while manufacturing was 31.1 and construction 7.1 per cent of the GPP. The services sector was also high with 51.1 per cent of the GPP.

Ontario reached a peak of mineral production value in 1974, then declined in 1975 due mainly to lower prices in some minerals, labour trouble and marketing problems, but increased to a new all-time high in 1976. Principal minerals were nickel, copper, zinc, iron ore and gold. The approximate distribution of mineral production by geographic region was Northeastern, 52 per cent; Northern, 17; Northwestern, 8; North Central, 7; and Southern, 16 per cent.

The James Ham report for the Ontario Royal Commission on health and safety of workers in mines criticized industry, provincial and federal governments for permitting high health hazards, especially in uranium mining. The Ontario government formed an Environmental Assessment Board to enquire into environmental aspects of proposed expansion in uranium mining and Ontario government projects will also have to undergo environmental assessment under new regulations taking effect in 1976.

Quebec. 1975: GPP = $37.3 billion (10.0 per cent increase and 23.2 per cent of the GNP). Mining = $1.24 billion (3.3 per cent of the GPP and 9.3 per cent of Canadian mineral production).

1976: Mining = $1.51 billion (+22.7 per cent and 9.9 per cent of Canadian mineral production).

The labour participation rate was 58.3 per cent. Unemployment was 8.7 per cent. Quebec was the second largest contributor to the GNP. Census values added (1974) indicated a primary production of only 7.0 per cent (mining 2.1 per cent, agriculture 1.9 and electric power 2.2 per cent). Secondary production was 36.0 and services 57.0 per cent of the GPP.

Principal minerals were asbestos, iron ore, copper and zinc. Asbestos production value increased by 94 and iron ore by 51 per cent during 1976. The Mount Wright project of Quebec Cartier Mining Company was under way at one-quarter capacity output. The Sept-Iles plant of Iron Ore Company of Canada, still in a tune-up stage, had increased production. Asbestos Corporation Limited was reactivating its King-Beaver asbestos open pit operation. Canadian Johns-Manville Company, Limited announced a $77-million expansion program at its Jeffrey asbestos mine. Depressed copper prices late in 1976 resulted in decisions to close copper mines in the Eastern Townships and the Gaspé. St. Lawrence Columbium and Metals Corporation at Oka has gone into receivership but the Niobec Inc. columbium mine in the Chicoutimi district started into production during 1976, and Campbell Chibougamau Mines Ltd. resumed limited mining at its Cedar Bay and Henderson mines in the Chibougamau area.

Mining developments were under way in Brouillan and La Gauchetiere townships in northwestern Quebec. Manitou-Barvue Mines Limited was planning to reopen its Zn-Ag Barraute township near Val d'Or. The Chibougamau area is going to be the target for an exploration program by six mining companies over five years in 28 townships and 6 200 square kilometres at a cost of $1.25 million. Campbell Chibougamau Mines Ltd. will lead the group of companies and operate the project.

New Brunswick: 1975: GPP = $2.17 billion (15.9 per cent increase and 2.1 per cent of the GNP). Mining = $232 million (10.7 per cent of the GPP and 1.7 per cent of Canadian mineral production).

1976: Mining = $255 million (+10.1 per cent and 1.7 per cent of Canadian mineral production).

The labour participation rate was 53.7 per cent and unemployment 11.2 per cent. Census values added (1974) indicated a primary production of 11.2 (fishing 3.2, mining 2.7), secondary 32.9 and a high service sector of 55.9 per cent of the GPP.

The chief minerals were zinc, lead, silver and copper. Metallics represent about 85 per cent of the minerals value and the principal mining area was the Bathurst district of northern New Brunswick. An antimony mine also operated at Lake George, south of Fredericton, and a coal mine in the Minto area.

A $200-million expansion at the Irving Refining Limited petroleum refinery at Saint John was completed during 1976. International Minerals & Chemical Corporation (Canada) Limited and the province have signed an agreement opening the way for exploration and development of a potash deposit near Salt Springs in Kings County. The provincial government was sponsoring an extensive drilling project to evaluate provincial coal reserves. The decision on whether or not to build an electrolytic zinc plant to treat zinc concentrates from Brunswick Mining and Smelting Corporation Limited was deferred for at least one year. Potash

Company of America, a division of Ideal Basic Industries of Denver, Colorado, announced its decision to proceed with development plans for a potash-salt deposit near Sussex. The New Brunswick government was given federal approval to build a $14 million deep-water oil terminal at Lorneville near Saint John. It will be used to supply oil to the Coleson Cove thermal power plant now under construction and for other uses and for other products.

Nova Scotia. 1975: GPP = $4.21 billion (11.3 per cent increase and 2.6 per cent of the GNP). Mining = $101 million (2.4 per cent of the GPP and 0.8 per cent of Canadian mineral production).

1976: Mining = $117 million (+15.6 per cent and 0.8 per cent of Canadian mineral production).

The labour participation rate was 55.2 per cent and unemployment 9.6 per cent. Census values added (1974) indicated a primary production of 7.9 (fishing 2.7, mining 2.3), secondary 24.8 and services at 67.3 per cent of the GPP, the highest of any province.

The principal minerals were coal, sand and gravel, gypsum and salt, with no significant production of metallic minerals. Major objectives in Nova Scotia were to increase coal production and discover uranium deposits. The Cape Breton Development Corporation (Devco) modernized one coal mine and opened two new mines near Sydney on Cape Breton Island. A proposed steel mill would also be located at Sydney. Both Nova Scotia and New Brunswick agreed to work with other coal-producing provinces and the federal government in establishing a new national coal policy. The Nova Scotia government wrote to major Canadian and international coal companies asking for proposals to develop coal reserves in the province. There are some 15 coal seams in the Pictou Basin of which at least five have economic potential. However, most accessible coal has already been mined and developers will face significant challenges to mine the remainder. Mines of less than 273 000 tonnes a year are considered as being not economically feasible to work.

High energy costs and high unemployment were continuing problems throughout the Atlantic provinces. Electric power generated by utilization of Bay of Fundy tides is a possibility and feasibility studies were being financed by the federal, Nova Scotia and New Brunswick governments.

Prince Edward Island. 1975: GPP = $459 million (0.9 per cent increase and 0.3 per cent of the GNP). Mining = $1.8 million (0.4 per cent of the GPP and 0.01 per cent of Canadian mineral production).

1976: Mining = $1.7 million (−4.9 per cent and 0.01 per cent of Canadian mineral production).

The participation rate was 57.0 per cent and unemployment 9.7 per cent. Census values added (1974) indicated a primary production of 18.4 (agriculture 14.3, fishing 2.7, electric power 1.4) secondary 17.6 and services 64.0 per cent of the GPP.

Sand and gravel were the only mineral commodities produced in the province.

Newfoundland and Labrador. 1975: GPP = $2.17 billion (9.8 per cent increase and 1.4 per cent of the GNP). Mining = $551 million (25.4 per cent of the GPP and 4.1 per cent of Canadian mineral production).

1976: Mining = $756 million (+37.2 per cent and 4.9 per cent of Canadian mineral production).

The labour participation rate was 49.4 per cent (the lowest in Canada) an unemployment 13.7 per cent (the highest in Canada).

Census values added (1974) indicated a primary production of 21.3 (mining 10.7, electric power 6.6, fishing 4.0), secondary 29.3 and services 49.3 per cent of the GPP.

Iron ore, zinc and asbestos were the principal minerals, with metallic minerals representing 93 per cent of the production value. Mineral production reached a peak in 1976, with iron ore production value increasing by 34.7 per cent. The chief centres of mineral production were the iron ore mines at Schefferville and Labrador City.

Exploration for oil and natural gas was under way off the coast of Labrador and four drilling vessels were probing for oil in 1976. Some $40-$50 million have been spent to date; one natural gas deposit was found but no major discoveries have been made. A 25 per cent "Canadian content" rule contained in new federal land regulations may limited further exploration but a $20 million program of drilling in deeper waters by major oil companies has been planned for this decade. The Come by Chance oil refinery went into receivership during 1976 but attempts were being made to refinance the project.

Mineral transportation

Mineral transportation issues in 1976 related largely to two factors: implementation of the transportation policy principles that had been announced by the Federal Minister of Transport in 1975, and the need for additional rail, port and shipping capacity to serve new coal developments.

The Minister of Transport has proposed numerous amendments to the National Transportation Act. While many relate to administration or organizational structure, one change that could have a large impact on the mineral industry is a proposed new formula to govern maximum and minimum levels of rail freight rates based on variable costs plus an allowance for fixed costs. Depending on how it is implemented, this proposal could lead to significant rate increases for low-value, bulk traffic such as minerals. Also proposed are amendments to the Canadian Maritime Code, including a provision restricting domestic coastal trade to Canadian built and registered vessels. While provision is made for use of foreign vessels in certain circumstances, opponents of the change fear it would lead to higher shipping costs, not only by ship but also by rail in the 15 to 25 per cent range. If the ratio is over 45 per cent, the royalty payable is the amounts for the above-noted two ranges plus 50 per cent of the operating profits above the 45 per cent ratio.

Operating profits for a year are calculated by deducting from gross sales the costs of production, a head office allowance, a marketing expense allowance, a working capital allowance, the basic royalty payable, a social capital cost allowance and a capital recovery allowance.

Capital investment for purposes of the regulations includes exploration, development and other capital expenditures, except social capital, expended to bring an operation into production. The unrecovered capital investment at the end of each year may be grossed up by a stipulated interest rate for purposes of the regulations. Major expenditures to capital assets after production is achieved may be allowed as an addition to capital investment.

Under specified conditions an exploration tax credit against graduated royalties may be allowed with respect to exploration expenditures made in the province. The credit can equal 35 per cent of accumulated exploration expenditures.

Lightweight Aggregates

D.H. STONEHOUSE

Aggregates commonly used to provide bulk in concrete and concrete products are sand, gravel and crushed stone. These commodities have an average unit weight of approximately 2000 kilograms a cubic metre. Until the mid-1940s comparatively little attention was paid to designing concrete products to meet a specific requirement other than a certain predetermined strength and setting time. At that time increased housing demand accentuated the need for prefabricated structures. Techniques of construction were developed using structural sections and panels of much lighter unit weight, with no sacrifice of strength, by utilizing lightweight aggregates, a variety of rock and mineral materials weighing in the neighborhood of 1300 kilograms a cubic metre.

Four categories generally used to classify the lightweight aggregates combine elements of source, processing methods and end-use. Natural lightweight aggregates include materials such as pumice, scoria, volcanic cinders and tuff. Manufactured lightweights are bloated or expanded products obtained by heating certain clays, shales, and slates. Ultra-lightweights are made from natural mineral ores, such as perlite and vermiculite, which are expanded or exfoliated by the application of heat and used mainly as plaster aggregate or as loose insulation. Fly ash, which is obtained from the combustion of coal and coke; and slag, which is obtained from metallurgical processes, are classed as byproduct aggregates.

The use of lightweight concrete in commercial and institutional projects has facilitated the construction of taller buildings and the use of longer clear spans in bridges and buildings. Additional advantages from the use of lightweight aggregates lie in the fact that they supply thermal and acoustical insulation, fire resistance, good freeze-thaw resistance, low water absorption and a degree of toughness to the concrete product.

Canadian industry and developments

All types of lightweight aggregates are used in Canada, but only expanded clays, shale and slag are produced from materials of domestic origin. Vermiculite is imported mainly from Montana, U.S.A., although a small amount is brought in from the Republic of South Africa. Perlite is imported mainly from New Mexico and Colorado, and pumice is imported from Oregon and Greece. Most processed lightweight aggregate is utilized in the construction industry, either as loose insulating material or as aggregate in the manufacture of lightweight concrete units. The scope of such applications has not yet been fully investigated.

Any lightweight material with acceptable physical and chemical characteristics could substitute for the mineral commodities generally used. The most significant substitute for vermiculite, for instance, is styrofoam or polyurethane, which offers insulating value and comparable strength. However, these materials are petroleum-based and higher fuel prices could limit their use. Mineral wool is a competitive insulation material but its manufacture requires a pyroprocessing stage as does the production of perlite and vermiculite. Transportation costs for high-bulk, lightweight materials are high; those materials, such as perlite and vermiculite, that can be transported to a consuming centre prior to expansion, have obvious advantages.

Perlite. Perlite is a variety of obsidian or glassy volcanic rock that contains 2 to 6 per cent of chemically combined water. When the crushed rock is heated rapidly to a suitable temperature (1400°F to 1800°F) it expands to between 4 and 20 times its original volume. Expanded material can be manufactured to weigh as little as 30 to 60 kilograms a cubic metre, with attention being given to preblending of feed to the kiln and retention time in the flame. Thermal conductivity (Btu's per hour per square foot per °F per inch of thickness) ranges as low as 0.267 for loosely packed perlite with a bulk density of 70 kilograms a cubic metre to 20 kilograms for perlite gypsum plaster.

In Canada, imported perlite is expanded and used mainly by gypsum products manufacturers in plaster products such as wallboard or drywall, and in fibre-perlite roof insulation board, where its value as a lightweight material is augmented by its fire-resistant qualities. It is also used as a loose insulation and as an insulating medium in concrete products. Perlite, vermiculite, and expanded shale and clay are becoming

Table 1. Canada, production of lightweight aggregates, 1975-1976

	1975		1976	
	m^3	$	m^3	$
From domestic raw materials				
Expanded clay, shale and slag	566 254	5 421 956	661 908	7 530 095
From imported raw materials				
Expanded perlite and exfoliated vermiculite	644 340	11 458 543	589 864	11 831 545
Pumice	40 776	485 997	49 030	748 145
Total	1 251 370	17 366 496	1 300 802	20 109 785

Source: Company data.

more widely used in agriculture as soil conditioners and fertilizer carriers.

Imports of crude perlite for consumption in Canada are from New Mexico and Colorado deposits, worked by such companies as Johns-Manville Corporation, United States Gypsum Company, United Perlite Corp. and Grefco Inc. In 1976 seven companies at nine locations in Canada reported production of expanded perlite.

Perlite occurs in British Columbia but no commercial deposits have as yet been located.

Pumice. Pumice is a cellular, glassy lava, the product of explosive volcanism, usually found near geologically-recent or active volcanoes. It is normally found as a loosely compacted mass composed of pieces ranging in size from large lumps to small particles. It is not the lightest of the lightweight aggregates, but when utilized as a concrete aggregate, particularly for the manufacture of concrete blocks, it exhibits strength, density and insulating values that have made it a preferred material.

In Canada, a number of concrete products manufacturers use pumice imported from Greece or from the northwestern United States, mainly in the manufacture of concrete blocks. A major use for pumice, as yet unexplored in Canada, has been in highway construction, where lightweight aggregate surfaces have been shown to have exceptional skid resistance.

Pumicite, distinguished from pumice by its finer size range (usually minus 100 mesh), is used in concretes mainly for its pozzolanic qualities. (A pozzolan is a siliceous material possessing no cementitious qualities until finely ground, in which form it will react with calcium hydroxide in the presence of moisture to form insoluble calcium silicates).

Extensive beds of pumicite have been noted in Saskatchewan and British Columbia.

Vermiculite. The term vermiculite refers to a group of micaceous minerals, hydrous magnesium-aluminum silicates, that exhibit a characteristic lamellar structure and expand or exfoliate greatly upon being heated rapidly. Mining is normally by open-pit methods, and beneficiation techniques include the use of hammer mills, rod mills, classifiers, screens, dryers and cyclones. Exfoliating is done in oil- or gas-fired, vertical or inclined furnaces, usually close to the consuming facility to obviate the higher costs associated with shipping the much-bulkier expanded product. Required temperatures can vary from 2000°F to 3500°F depending on the type of furnace in use. A controlled time and temperature relation is critical in order to produce a product of minimum bulk density and good quality.

The expansion process has advanced technologically to permit production of various grades of expanded vermiculite as required. The uses to which the product is put depend on its low thermal conductivity, its fire-resistance and, more recently, on its lightweight qualities.

Canadian consumption is mainly as loose insulating material, with smaller amounts being used as aggregate in the manufacture of insulating plaster and concrete. The energy situation will undoubtedly continue

Table 2. Canada, consumption of expanded clay and shale, percentage by use, 1974-1976

Use	1974	1975	1976
Concrete block manufacture	65.6	77.4	70.7
Precast concrete manufacture	4.2	10.9	10.8
Ready-mix concrete	24.0	7.0	12.7
Horticulture & miscellaneous	6.2	4.7	5.8

Source: Company data.

to result in increased domestic fuel costs, and greater use of insulation in both new construction and older buildings will continue to tax the production capability of manufacturers for some time.

The major producer of vermiculite is the United States. The principal company supplying Canada's imports is W.R. Grace and Company, from operations at Libby, Montana. Canada also imports crude vermiculite from the Republic of South Africa, where Palabora Mining Co. Ltd. is the major producer. At both the Grace and Palabora operations milling limitations have necessitated new mill installations in an effort to keep up with demand. Minor amounts of vermiculite are produced in Argentina, Brazil, India, Kenya and Tanzania.

Vermiculite occurrences have been reported in British Columbia, and deposits near both Perth and Peterborough in Ontario have been investigated but, as yet, no commercial deposits have been developed in Canada.

Three companies operated a total of eight vermiculite processing plants in Canada during 1976.

Table 3. Canada, consumption of expanded perlite, percentage by use, 1974-1976

Use	1974	1975	1976
Insulation	92.0	91.1	86.0
— loose			(3.8)
— in plaster			(13.9)
— in other construction materials			(68.3)
Horticulture	5.0	5.2	8.5
Other (fillers, coatings)	3.0	3.7	5.5

Source: Company data.

Clay, shale and slag. Common clays and shale are used throughout Canada as raw material for the manufacture of lightweight aggregates. Although the Canadian industry began in the 1920s in Ontario, it did not evolve significantly until the 1950s when it grew in support of demands from the construction industry. The raw materials are usually quarried adjacent to the plant sites at which they are expanded. Clays receive little beneficiation other than drying before being introduced to the kiln in which they are heated. Shales are crushed and screened before burning. Six plants in Canada produced lightweight aggregates from clay and shale during 1976, each using a rotary kiln process.

One company produces an aggregate material from slag as a byproduct of a blast furnace operation. In steelmaking, iron ore, coke and limestone flux are melted in a furnace. When the metallurgical process is completed, lime has combined with the silicates and aluminates of the ore and coke and formed a nonmetallic product (slag) which can be subjected to controlled cooling from the molten state to yield a porous, glassy material. Slag has many applications in the construction industry. The statistics relative to expanded slag production are included in those of clay and shale.

Although Canada does not produce large amounts of fly ash, the technology of fly-ash processing and utilization is well advanced. The largest single use for fly ash is as a cementitious material, in which application its pozzolanic qualities are utilized. Use of fly ash as a lightweight aggregate could become of increasing importance. Great West Industries (Alta) 1976 Ltd. of Edmonton, Alberta, which produces brick using fly ash and bottom ash as raw material, was taken over by Great West Steel Industries Ltd. of Vancouver in 1972. Ontario Hydro produces over 400 000 tonnes* of fly ash a year from three coal-fired stations. Experimentation continues towards successful utilization of this material at the Lakeview plant in the production of pozzolan, iron oxide and lightweight pellets. Disposal costs of $2 to $3 a tonne add incentive to such programs.

Table 4. Canada, consumption of exfoliated vermiculite, percentage by use, 1974-1976

Use	1974	1975	1976
Insulation			
— loose	75.0	77.0	71.9
— in concrete & concrete products	3.7	3.9	7.3
— in plaster	2.2	1.0	2.0
Horticulture	8.0	8.8	8.8
Other (fireproofing, barbecue base)	11.1	9.3	10.0

Source: Company data.

Specifications

There are as yet no Canadian Standards Association (CSA) specifications for the lightweight aggregates. Production and application are based on the American Society for Testing and Materials (ASTM) designations as follows: ASTM Designations C 332-56 T — Lightweight Aggregates for Insulating Concrete; C 330 — Lightweight Aggregates for Structural Concrete; and C 331 — Lightweight Aggregates for Concrete Masonry Units.

Outlook

Demand for all lightweight aggregates will continue to increase as their use in structural concrete and for insulation purposes becomes more popular. In view of

*The term "tonne" refers to the metric ton of 2 204.62 pounds.

Table 5. Lightweight aggregate plants in Canada, 1976

Company	Location	Product
Atlantic Provinces		
Avon Aggregates Ltd.	Minto, N.B.	Expanded shale
Quebec		
F. Hyde & Company, Limited	Montreal	Vermiculite
Laurentide Perlite Inc.	Charlesbourg West	Perlite
Masonite Canada Ltd.	Gatineau	Perlite
Perlite Industries Reg'd.	Ville St. Pierre	Perlite
Vermiculite Insulating Limited	Lachine	Vermiculite
Ontario		
Canadian Gypsum Company, Limited	Hagersville	Perlite
Canadian Johns-Manville Company, Limited	North Bay	Perlite
Domtar Construction Materials Ltd.	Caledonia	Perlite
	Mississauga	Expanded shale
	Cornwall	Perlite
Grace Construction Materials Ltd.	St. Thomas	Vermiculite
	Ajax	Vermiculite
National Slag Limited	Hamilton	Slag
Prairie Provinces		
Cindercrete Products Limited	Regina, Sask.	Expanded clay
Consolidated Concrete Limited	Calgary, Alta.	Expanded shale
Domtar Construction Materials Ltd.	Calgary, Alta.	Perlite
Echo-Lite Aggregate Ltd.	St. Boniface, Man.	Expanded clay[1]
Consolidated Concrete Limited Edcon Block Division	Edmonton, Alta.	Expanded clay
Grace Construction Materials Ltd.	Winnipeg, Man.	Vermiculite
	Edmonton, Alta.	Vermiculite
Kildonan Concrete Products Ltd.	St. Boniface, Man.	Expanded clay
Northern Perlite & Vermiculite Limited	St. Boniface, Man.	Vermiculite
British Columbia		
Grace Construction Materials Ltd.	Vancouver	Vermiculite
Westroc Industries Limited	Vancouver	Perlite

Source: Company data.
[1]Plant closed in 1975

increased costs of energy the amount of insulation which can be economically installed in new housing and, indeed, in older housing, has about doubled during the past few years thereby placing great demand pressure on the suppliers of these materials. The four main lightweight materials — perlite, pumice, vermiculite and expanded clays — are interchangeable for many applications and can, along with some synthetic materials, be considered substitutes or alternates for each other.

The United States is the source of most of the lightweight raw materials consumed in Canada, exclusive of clay, shale and slag. The U.S. reserves are sufficient both for its domestic requirements and for exports to meet Canada's projected needs for many years.

World review

The United States and Greece are the main producers of perlite; smaller quantities are mined in Algeria, Turkey, the Philippines and New Zealand. New Zealand could become a major producer if huge deposits owned by Consolidated Silver Mining Co. are developed for export markets.

The major producers of pumice include the United States, Italy, West Germany and Greece, although production is recorded from other countries. As with other low-cost lightweight material, transportation costs are the main factor in determining the competitiveness of pumice. Prices have not varied greatly in recent years.

The use of fly ash should increase with the added incentives provided by environmental control. Two cement companies in the United States have begun to blend fly ash with portland cement at three plants to produce portland-pozzolan cement for general construction use. Using only about 20 per cent of ash production, industry in North America falls far short of European enterprises which use as much as 80 per cent of production.

In the United States, W.R. Grace and Company, Zonolite Division, is by far the largest producer of vermiculite, with mines in Montana and South Carolina. Through the Palabora Mining Co. Ltd. the Republic of South Africa remains the second-largest producer.

The unit price has shown a steady but unspectacular rate of increase during the past few years and is likely to continue to do so in pace with a steady increase in demand and inflationary conditions, each of which could have as its main contributing influence increased costs of energy, particularly the fossil fuels.

Aluminum

M.J. GAUVIN

Noncommunist world demand for aluminum in 1976 increased more than 25 per cent from the low levels recorded in 1975. Demand increased gradually during the year and noncommunist producers were able to reduce their inventories to near normal levels while increasing their operating rates from an average of 81 per cent of capacity at the beginning of the year to almost 89 per cent at year-end. Canadian production suffered a severe setback because of strikes at the Quebec smelters of the Aluminum Company of Canada, Limited. Producers in other countries were able to increase their operating rates to counter-balance the decreased Canadian production. Two increases in the quoted price of primary ingot totalling seven cents were announced by producers, which raised the North American price from 41 cents to 48 cents a pound during the year.

Canada

No economic deposits of bauxite, the predominant ore of aluminum, are found in Canada. Bauxite is imported for the production of alumina by the Bayer process. Alumina is an aluminum oxide intermediate product which is reduced in an electric furnace to aluminum metal by the Hall-Heroult process. Approximately 4.5 tonnes* of bauxite are refined to two tonnes of alumina, which in turn are smelted to obtain one tonne of aluminum. The Hall-Heroult process involves high consumption of electric power; from 7 to 8 kWh per pound of aluminum produced. For this reason, Canada's aluminum smelters are advantageously located near large low-cost power sources. Also, because transportation costs are such an important factor in the import of raw materials and export of aluminum, these smelters are all located near ocean shipping ports.

Production

Canadian primary aluminum output decreased to 633 428 tonnes in 1976 from the 887 023 tonnes produced in 1975. The two companies which operate primary aluminum smelters in Canada are the Aluminum Company of Canada, Limited (Alcan), a subsidiary of Alcan Aluminium Limited of Montreal (also referred to as Alcan) and Canadian Reynolds Metals Company, Limited, a subsidiary of Reynolds Metals Company of Richmond, Virginia. With the strengthening of demand, Reynolds reactivated, early in the year, the 24 300 tonnes of annual capacity it had shut down in 1975. However, Alcan, because of labour strikes, was able to reactivate idled capacity only at its Kitimat, British Columbia, smelter which was operating at capacity late in the year. The prolonged work stoppages at its Quebec plants were the reason for Canada's reduced production in 1976.

Some 1 230 052 tonnes of bauxite were imported from Guinea, Guyana, Surinam and elsewhere to produce alumina at Alcan's refinery at Arvida, Quebec, the only alumina refinery in Canada. It has a capacity of 1 258 300 tonnes a year and supplies Alcan's four smelters in Quebec. Alumina for use at Alcan's Kitimat smelter was imported mainly from Australia.

In 1976, Alcan's Canadian smelters produced 492 600 tonnes of primary aluminum compared with an output of 760 200 tonnes in 1975. Three smelters in Quebec with a total annual capacity of 552 500 tonnes were on strike from June 3 to November 15 but had returned to pre-strike operating levels by the end of the year. At year-end, Alcan's Shawinigan, Quebec, smelter with an annual capacity of 82 500 tonnes had been on strike for two months. Alcan Aluminium Limited, a multi-national company, has wholly- and partially-owned smelters in Japan, Norway, Spain, Great Britain, India, Sweden, Brazil and Australia. Alcan's total production in 1976, including Canadian production, was 1 517 700 tonnes, compared with 1 830 700 tonnes in 1975.

The Canadian Reynolds Metals Company, Limited operates a smelter at Baie-Comeau, Quebec. Its production in 1976 was 138 400 tonnes, an increase of 15

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

per cent from the 119 500 tonnes produced in 1975.

Alcan is planning to rebuild its existing Canadian smelters and increase smelting capacity by 270 000 tonnes. The timing of this program is flexible, being governed by the prospect for adequate financial return. The long-term plan includes building a new 181 400-tonne-a-year smelter on a 2 400-acre site near La Baie, Quebec.

Alcan commissioned a second high-speed cold-rolling mill at its Kingston, Ontario works which increased the plant's capacity to 135 000 tonnes a year. The company also expanded its continuous casting and rolling capabilities at Jonquière, Quebec. Canadian Reynolds began continuous strip casting for production of aluminum siding at its expanded Cap-de-la-Madeleine, Quebec plant.

Canadian exports of aluminum, mainly in ingot form, but also including further fabricated materials, were 535 707 tonnes; almost unchanged from the 533 739 tonnes exported in 1975. The value of 1976 exports was $496 172 000 compared with $464 370 000 in 1975, an increase of 6.9 per cent.

Consumption

Canadian consumption of aluminum is estimated at 331 000 tonnes for 1976, an increase of 12.9 per cent from the 293 280 tonnes consumed in 1975.

World Review

World production of bauxite was 79.6 million tonnes in 1976, little changed from the 79.4 million tonnes produced the previous year. Australia, the world's largest producer, produced 23.5 million tonnes in 1976, compared with 20.3 million tonnes in 1975. Guinea and Jamaica were the next-largest producers with production in 1976 of 11.3 and 10.3 million tonnes respectively. World production of aluminum increased marginally from 12.70 million tonnes in 1975 to 12.76 million tonnnes in 1976. Increased world consumption of aluminum in 1976 allowed noncommunist world producers to reduce their inventory of primary aluminum from 3.1 million tonnes at the end of 1975 to 2.3 million tonnes at the end of 1976. Noncommunist world aluminum producers increased their operating rate from 81 per cent of capacity in December 1975 to almost 89 per cent of capacity at the end of 1976.

The International Bauxite Association (IBA), formed to further the interests of the bauxite-producing nations, consists of 11 member countries. Australia, Guinea, Guyana, Jamaica, Sierre Leone, Surinam and Yugoslavia were the founding members when the IBA was formed at Conakry, Guinea in March 1974; Haiti, Ghana and the Dominican Republic joined the Association at its meeting in Georgetown, Guyana in November 1974, and Indonesia became a member at the second annual meeting held in Kingston, Jamaica in 1975. The IBA has not been successful in its attempt to develop a uniform pricing policy for bauxite, and the member countries have established or negotiated their own bauxite levies. However, the IBA is still in the early stages of development. It can be an important forum for bauxite producers in which common problems can be discussed and it could eventually succeed in its main objectives.

Jamaica, one of the leaders of the IBA, has one of the highest levies for bauxite. Under its Bauxite Production Levy Act, passed in 1974, the government has the right to acquire equity participation in the bauxite mining operations on the island and to buy back the lands held by the aluminum companies. The rate of levy, based on the average U.S. price of a short ton of aluminum ingot, was set at 7½ per cent for 1974, rising to 8½ per cent in 1976. In October the Aluminum Company of America (Alcoa) and the Jamaican government concluded an agreement on ownership of Alcoa's operation and an eight-year understanding for a reduction on the bauxite levy to 7½ per cent. Under the agreement a joint Alcoa-Jamaica mining-refining venture called Jamalco will be formed; Alcoa will sell 6 per cent of its mining and refining assets and all of Alcoa's mining and non-operating land to Jamaica. Jamalco has been given mining leases assuring the venture of 40 years' supply of bauxite. As part of the agreement, Alcoa is to withdraw its case against Jamaica with the International Center for the Settlement of Investment disputes. Similar agreements in principle have been reached between the Jamaican government and Kaiser Aluminum & Chemical Corporation and Reynolds Metals Company on their Jamaican bauxite operations. An agreement between Jamaica and Revere Copper and Brass Incorporated, reached in 1974, tied the bauxite levy reduction to the construction by Revere of a 540 000-tonne expansion of its alumina refinery in Jamaica. Revere shut down its Jamaican bauxite and alumina operations in August 1975 as a result of cutbacks in aluminum production in the United States. It's Maggotty, Jamaica plant has since remained idle and Revere has been purchasing its alumina requirements elsewhere. The government is claiming a production levy for the bauxite not mined. Revere has challenged the legality of the Jamaican legislation and has also filed a $80 million claim with the United States Overseas Private Investment Corporation claiming that the Jamaican government has in effect taken over the operation.

Jamaica, Guyana, and Trinidad and Tobago have been examining the feasibility of constructing a 75 000-tonne-a-year smelter in Trinidad based on local natural gas and Jamaican alumina. A second proposed smelter to be built by the three countries would be in Guyana, based on domestic bauxite and power from a hydroelectric project that has yet to be built. Jamaica and Mexico are also considering the feasibility of constructing a jointly owned 150 000-tonne-a-year smelter in Mexico.

Table 1. Canada, aluminum production and trade, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production	887 023	. .	633 428	. .
Imports				
Bauxite ore				
Surinam	104 420	4 689 000	133 703	9 171 000
Guinea	1 142 186	15 064 000	522 686	7 921 000
United States	17 432	1 283 000	48 078	3 773 000
Guyana	820 674	7 659 000	299 519	2 964 000
Australia	—	—	29 049	1 942 000
People's Republic of China	—	—	24 987	1 509 000
Other countries	335 956	3 338 000	172 030	1 789 000
Total	2 420 668	32 033 000	1 230 052	29 069 000
Alumina				
Australia	404 033	49 413 000	427 369	50 666 000
United States	211 503	30 698 000	293 526	47 365 000
West Germany	35 319	6 037 000	83 616	13 105 000
Jamaica	78 901	10 220 000	39 709	5 320 000
France	187	430 000	41 608	3 161 000
Netherlands Antilles	—	—	22 097	2 489 000
Other countries	30 672	2 832 000	30	17 000
Total	760 615	99 630 000	907 955	122 123 000
Aluminum and aluminum alloy scrap	7 010	1 320 000	9 136	4 262 000
Aluminum paste and aluminum powder	2 909	3 004 000	5 423	6 163 000
Pigs, ingots, shots, slabs, billets, blooms and extruded wire bars	18 302	17 215 000	22 545	21 023 000
Castings	941	3 216 000	1 868	4 034 000
Forgings	439	2 272 000	333	1 822 000
Bars and rods, nes	1 553	2 451 000	2 286	3 446 000
Plates	4 849	6 490 000	8 738	11 086 000
Sheet and strip up to .025 inch thick	14 686	16 535 000	16 592	20 229 000
Sheet and strip over .025 inch up to .051 inch thick	3 296	4 827 000	5 773	9 091 000
Sheet and strip over .051 inch up to 1.25 inch thick	9 615	10 504 000	28 312	30 693 000
Sheet over 1.25 inch thick	18 468	19 247 000	19 428	21 901 000
Foil or leaf	693	1 184 000	465	780 000
Converted aluminum foil	. .	3 755 000	. .	. .
Structural shapes	1 547	3 740 000	1 272	2 672 000
Pipe and tubing	1 294	3 163 000	1 088	2 978 000
Wire and cable excl. insulated	1 128	2 186 000	1 684	3 033 000
Aluminum and aluminum alloy fabricated materials, nes	. .	15 102 000	. .	21 796 000
Total aluminum imports		116 211 000		165 009 000

Table 1. (cont'd)

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Exports				
Pigs, ingots, shot, slab, billets, blooms, and extruded wire bars				
United States	309 480	249 474 000	356 073	303 948 000
People's Republic of China	33 005	24 142 000	22 895	16 303 000
United Kingdom	11 754	10 118 000	16 085	12 986 000
Hong Kong	12 203	10 287 000	17 413	12 545 000
Turkey	12 409	9 116 000	13 399	10 977 000
Brazil	17 474	13 878 000	13 088	10 399 000
Japan	40 914	28 215 000	8 748	7 991 000
Israel	2 525	2 050 000	8 854	6 877 000
Malaysia	5 270	4 196 000	6 287	5 930 000
Nigeria	6 826	5 787 000	5 035	4 710 000
Colombia	2 611	2 381 000	5 123	4 227 000
Other countries	54 865	43 669 000	34 510	30 290 000
Total	509 336	403 313 000	507 510	427 183 000
Casting and forgings				
United States	466	5 510 000	811	5 819 000
France	82	1 029 000	9	573 000
United Kingdom	72	447 000	9	477 000
Netherlands	9	244 000	9	447 000
Other countries	9	264 000	56	398 000
Total	638	7 494 000	894	7 714 000
Bars, rods, plates, sheets and circles				
Venezuela	115	204 000	8 357	7 419 000
United States	4 089	4 129 000	3 598	3 959 000
Pakistan	—	—	2 628	2 903 000
Algeria	—	—	500	466 000
Jamaica	345	414 000	304	417 000
Sri Lanka	2	1 000	299	373 000
Switzerland	368	555 000	242	365 000
El Salvador	—	—	401	350 000
Trinidad-Tobago	259	342 000	215	303 000
South Africa	249	312 000	220	242 000
Other countries	2 332	2 350 000	636	886 000
Total	7 759	8 307 000	17 400	17 683 000
Foil				
Venezuela	109	175 000	268	488 000
Costa Rica	—	—	28	41 000
United States	27	75 000	7	20 000
New Zealand	5	9 000	9	16 000
Brazil	18	30 000	—	—
Other countries	425	708 000	3	8 000
Total	584	997 000	315	573 000

Table 1. (concl'd)

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Fabricated materials, nes				
United States	6 160	6 872 000	6 949	8 907 000
Pakistan	2 508	3 054 000	1 272	1 771 000
United Kingdom	413	889 000	241	545 000
Dominican Republic	383	456 000	315	495 000
Tunisia	1 021	1 437 000	243	351 000
Nigeria	603	355 000	166	280 000
Other countries	4 334	4 811 000	402	634 000
Total	15 422	17 874 000	9 588	12 983 000
Ores and concentrates				
United States	18 242	3 254 000	13 100	2 434 000
United Kingdom	1 100	243 000	1 089	198 000
Spain	1 276	213 000	577	97 000
France	1 297	225 000	625	79 000
West Germany	156	30 000	144	39 000
Italy	762	134 000	142	17 000
Other countries	930	202 000	135	27 000
Total	23 763	4 301 000	15 812	2 891 000
Scrap				
United States	31 328	17 813 000	41 002	21 609 000
Japan	2 999	1 423 000	6 234	3 986 000
West Germany	2 746	1 044 000	1 678	640 000
Brazil	362	140 000	731	434 000
Italy	636	306 000	330	172 000
United Kingdom	179	101 000	637	162 000
Spain	2 669	523 000	339	81 000
Pakistan	27	15 000	62	26 000
Other countries	1 465	719 000	85	35 000
Total	42 411	22 084 000	51 098	27 145 000
Total aluminum exports		464 370 000		496 172 000

Source: Statistics Canada.
^{p} Preliminary; — Nil; . . Not available.

Brazil currently is a small producer of bauxite but she will rank among the world's largest exporters by the early 1980s. Companhia Vale do Rio Doce (CVRD), a state-owned company, is involved in several projects. Mineracao Rio do Norte S.A. is developing the Orximinia deposit on the Trombetas River in the Amazon region. Brazilian interests, led by CVRD, hold 51 per cent of the project, Alcan has 21.5 per cent and six other aluminum producers hold the remainder. Production is scheduled to begin in 1979. The initial planned capacity is 3.3 million tonnes of bauxite a year, of which Alcan is to receive 1.1 million tonnes. Expansion plans call for the capacity of the project to be increased to 7.3 million tonnes, of which Alcan will receive 2.2 million tonnes. The Trombetas project will supply bauxite to the Brazilian-Japanese joint venture, Aluminio Brasileiro Ltd. (Albras). Albras is owned 51 per cent by CVRD and the other 49 per cent is owned by Japanese interests led by five Japanese aluminum-smelting companies. The consortium will build an alumina refinery and an aluminum smelter near Belem with an initial capacity of 290 000 tonnes of aluminum a year. In addition, a hydroelectric power station will be built on the Tocantins River to supply power for the project. The $1.3 billion smelter-refinery project is scheduled to start production in

1981. The Aluminum Company of America (Alcoa) has filed a request for mining permits on bauxite concessions in the Amazon region and Rio Tinto Zinc Corporation Limited is negotiating with CVRD to form a joint venture to mine bauxite in the Amazon basin. Companhia Mineira de Aluminio (Alcominas), an Alcoa affiliate in which The Hanna Mining Company has a substantial interest, doubled the capacity of its Pocos de Caldas smelter to 60 000 tonnes. Construction began on a 27 000-tonne expansion of Alcan Aluminio do Brazil's Saramenha smelter and supporting aluminia facilities which will raise the plant's capacity to 59 000 tonnes of aluminum a year.

Table 2. Canada, primary aluminum production trade and consumption, 1965, 1970, and 1974-76

	Production	Imports	Exports	Consumption[1]
	(tonnes)			
1965	753 421	6 300	641 844	193 316
1970	962 541	12 179	761 671	250 150
1974	1 006 632	47 950	689 878	359 790
1975	887 023	18 302	509 336	293 280
1976[p]	633 428	22 545	507 510	331 000

Source: Statistics Canada.
[1]Excluding aluminum metal used in the production of secondary aluminum.
[p]Preliminary.

Australia, the world's largest producer of bauxite, increased its production to 23.5 million tonnes from the 21.3 million it produced in 1975 and increased its production of aluminum about 8.5 per cent. Bauxite production from the Weipe deposit of Comalco Limited, the largest single bauxite-mining operation in the world, increased marginally to 9.6 million tonnes. New Zealand Aluminum Smelters Ltd., 50 per cent owned by Comalco, completed the expansion of its Bluff, New Zealand smelter from 112 000 to 150 000 tonnes a year. In October, Comalco resumed work on the expansion of its smelter at Bell Bay, which will raise capacity by 18 900 tonnes to 114 500 tonnes in 1977. The company continued to examine the feasibility of building a smelter at Gladstone, Queensland. It has been announced that the Alwest project in Western Australia will proceed with the construction of an alumina refinery in Wagerup, Western Australia. The $650-million project will have an initial capacity of 800 000 to 1 million tonnes a year. Reynolds will have a 35 per cent interest and Alcoa of Australia Ltd., 20 per cent. The original Alwest partners, Dampier Mining Company Limited and News Ltd. are still involved in the project. Alcoa of Australia completed the expansion of its Pinjarra alumina refinery to 2 million tonnes from 800 000 tonnes. The alumina refinery of Queensland Alumina Ltd. at Gladstone produced 2.07 million tonnes of alumina in 1976, slightly above its design capacity of 2 million tonnes. Alcan Aluminium has a 21.39 per cent interest in Queensland Alumina.

Noranda Aluminum Inc. completed construction of a second potline at its New Madrid, Missouri smelter which doubled its capacity to 127 000 tonnes of aluminum a year. Alcoa constructed a primary aluminum potline at its Massena, New York operations to replace three smaller units that have been deactivated. Primary aluminum capacity at the plant has been increased to 186 000 tonnes. Alcoa started operations at its Anderson County, Texas plant where the Alcoa Smelting Process is being evaluated. It uses 30 per cent less energy in the smelting cell than the most energy-efficient Hall-Heroult Process equipment. Capacity of the unit is 13 600 tonnes and a second unit of similar size is under construction. Alcan Aluminum Corporation began operation of its second cold-rolling mill in its Oswego, N.Y. plant. A power crisis is facing the aluminum producers in the northwest United States where about 30 per cent of the U.S. smelter capacity is located. The Bonneville Power Administration is preparing to notify smelters that their power contracts will not be renewed when they expire in the mid-1980s and the smelters in the area may be forced to use expensive thermal or nuclear power.

In Japan, the Ministry of International Trade and Industry (MITI) set production guidelines for the aluminum industry which resulted in smelters operating at about 60 per cent of capacity for the first three-quarters of the year. The smelters then increased production to about 70 per cent of capacity at the end of the year. By controlling their production, the smelters were able to reduce their inventories to normal operating levels. Mitsui Aluminum Company completed the expansion of its Wakamatsu alumina plant which doubles its annual capacity to 360 000 tonnes.

P.T. Indonesia Asahan Aluminum Company has been established by the government of Indonesia and Nippon Asahan. The Asahan project involves a 204 000-tonne-a-year aluminum smelter and a 510-megawatt power plant on the Asahan River in northern Sumatra. The first 68 000 tonnes of capacity is expected to be on stream by 1981 and full capacity is scheduled for 1893.

In Yugoslavia, the state company, Energoinvest Corporation has completed its 254 000-tonne-a-year alumina plant at Mostar and has started construction of a 77 000-tonne smelter at the same site. Energoinvest is also building a 600 000-tonne-a-year alumina plant with an integrated smelter at Zvormik. Contracts have been signed for the construction in the United Arab Emirates of a $500-million aluminum smelter designed to produce 136 000 tonnes of primary ingot a year. The plant, to be built by British Smelter Constructions Ltd. and managed by Southwire Aluminum Company, is scheduled for completion by 1981.

Table 3. Canada consumption of aluminum at first processing stage

	1973	1974	1975	1976[p]
	(tonnes)			
Castings				
Sand	1 632	1 715	1 292	
Permanent-mould	13 544	13 937	13 153	
Die	24 983	20 926	17 310	
Other	12	2	. .	
Total	40 171	36 580	31 755	. .
Wrought products				
Extrusions including tubing	92 535	96 140	77 989	
Sheet, plate, coil and foil	117 214	141 721	106 175	
Other wrought products (including rod, forgings and slugs)	69 412	73 705	64 469	
Total	279 161	311 566	248 633	. .
Destructive uses				
Non-aluminum base alloys, powder and paste deoxidizers and other	12 450	11 644	12 892	. .
Total consumed	331 782	359 790	293 280	331 000
Secondary aluminum[1]	38 781	36 155	31 201	. .

	Metal entering plant		On hand December 31	
	1974	1975	1974	1975
Primary aluminum ingot and alloys	344 300	269 620	88 527	83 049
Secondary aluminum	30 040	26 236	3 184	2 586
Scrap originating outside plant	49 063	15 071	9 417	1 940
Total	423 403	310 927	101 128	87 575

Source: Statistics Canada.
[1]Aluminum metal used in the production of secondary aluminum.
[p]Preliminary; . . Not available.

Stockpiles

New long-term stockpile goals were announced by the United States General Services Administration (GSA). The new stockpile objectives are the result of a new policy which calls for a material stockpile supporting U.S. defense requirements and basic civilian requirements during a major war and over a three-year period. The new goals would, if accepted by Congress, reduce the quantity of bauxite GSA holds and embark it on a program of acquiring 10.4 million tonnes of alumina which is not stockpiled at present. The new GSA goal for aluminum metal remained at zero.

The Light Metal Stockpiling Association was formed in Japan and it purchased 9 570 tonnes of aluminum ingot from local smelters at a price of about 48.5 cents a pound with $10 million which it received in government-backed, low interest loans.

Table 4. World primary aluminum production and consumption, 1975 and 1976

	Production		Consumption	
	1975	1976[p]	1975	1976[e]
	(thousand tonnes)			
United States	3 519.1	3 810.2	4 132.2	4 045.6
Europe[1]	3 234.6	3 260.4	2 819.4	3 291.2
Japan	1 013.3	895.3	1 248.2	1 615.9
Canada	887.0	633.4	293.3	280.0
Australia and New Zealand	322.8	365.9	163.3	193.9
Asia (excluding Japan and China)	396.6	436.5	412.0	411.6
Africa	273.0	326.5	128.0	128.0
America (excluding United States and Canada)	264.5	258.5	405.1	416.0
Sub-total	9 910.9	9 986.7	9 601.5	10 382.2
Communist countries[2]	2 790.6	2 770.2	2 702.0	2 702.0
Total	12 701.5	12 756.9	12 303.5	13 084.2

Sources: World Bureau of Metal Statistics; for Canada, Statistics Canada; for United States production, US Bureau of Mines Commodity Data Summaries.
[1]Includes Yugoslavia; [2]Excludes Yugoslavia.
[p]Preliminary; [e]Estimated.

Technology

Pechiney Ugine Kuhlmann Development, Inc. and Alcan Aluminium completed construction in September on their jointly owned pilot plant near Marseilles, France for the development of a process to produce alumina from non-bauxitic materials such as clays and shales. The plant is designed to produce 18 tonnes a day of high-grade alumina using Pechiney's H-Plus process. The process is said to produce a purer alumina than that resulting from the traditional Bayer process and thus reduce smelting costs. It is expected that sufficient data to accurately assess the process will be available by 1979. Estimated capital costs and operating expenses of the plant are about $25 million.

The U.S. Bureau of Mines has been conducting a series of "miniplant" research tests to develop an efficient and economical process to produce alumina from non-bauxitic, alumina-bearing minerals which are plentiful but have not been considered a practical source of alumina. The tests being conducted at the Bureau's Boulder City, Nevada, laboratory are co-sponsored by nine firms involved with alumina technology. The aim of the tests is to develop the technology to produce alumina and ensure an adequate supply for the United States in the event of problems of access to bauxite from other countries.

Uses

Characteristics such as lightness, combined with strength, pleasing appearance, corrosion resistance, conductivity and heat reflectivity, provide many advantages favouring the use of aluminum. It may be cast, rolled, extruded and forged with ease compared with many of its competitive materials. In the United States, by far the world's largest market, the construction field continued to be the largest consumer in 1976, accounting for 23 per cent of shipments, according to the Aluminum Association. Containers and packaging was in second place with 20 per cent, followed by transportation, 19 per cent; electrical uses, 10 per cent; consumer durables, 8 per cent; and machinery and equipment, 7 per cent. In many of the other main consuming countries, transportation ranks first as a consumer.

Shipments to major markets by United States producers increased 28 per cent from the depressed level of 1975. Shipments in 1976 totalled 5.78 million tonnes, compared with 4.5 million tonnes in 1975.

The average automobile manufactured in North America in 1973 contained 76 pounds of aluminum. Aluminum usage in passengers cars has increased to 87 pounds in the 1976 model year and 100 pounds in the 1977 model year. By 1980, the Aluminum Association expects the average new car will contain between 150 and 175 pounds of aluminum. The trucking industry is turning more to the use of aluminum and as transportation costs continue escalating, aluminum use

Table 5. Canadian primary aluminum smelter capacity, 1976

Smelter location	Annual capacity
	(tonnes)
Aluminum Company of Canada, Limited	
Quebec	
Arvida	399 200
Isle-Maligne	98 000
Shawinigan	82 500
Beauharnois	46 300
British Columbia	
Kitimat	267 600
Total Alcan capacity	893 600
Canadian Reynolds Metals Company, Limited	
Quebec	
Baie-Comeau	158 800
Total Canadian capacity	1 052 400

Source: Compiled from various company reports by the Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

will grow because it provides substantial weight and fuel savings. The aluminum industry is promoting the use of aluminum in solar energy collector units. There is a rapidly growing trend towards more solar energy systems, and solar plate production in the United States more than doubled in the past year and is expected to continue its increase.

Prices

Published prices for aluminum and aluminum products moved steadily upward during the year, starting in February when United States producers increased the price of certain flat-rolled aluminum products by 2 to 4 cents a pound. In April, North American producers announced a price increase from 41 cents to 44 cents a pound for primary ingot, to become effective in June. In August, the price of ingot was increased to 48 cents. Other world producers posted similar increases.

Outlook

The slow economic recovery of 1976 is expected to continue in 1977, with the United States market showing the best rate of recovery. While producers of other nonferrous metals continue to experience the full impact of the recession and are not yet on the path of recovery, the aluminum industry proved to be unique in that it was able to rationalize production, keep inventory levels under control, raise prices and generally maintain a satisfactory level of profits. There is good reason to expect that producers will continue to maintain their self-discipline and the financial viability of the industry.

The building and construction industry is expected to show the largest increase in consumption of aluminum during 1977. With producer inventories at near-normal levels, producers will increase capacity utilization as demand increases. Some increases in aluminum prices can be expected.

No aluminum shortage is foreseen for the next four or five years. Worldwide expansion plans are only modest for the balance of this decade and some additional capacity will be required to meet anticipated demand after 1980.

The need to conserve energy will spur the growth of the recycling industry. Recycled aluminum consumes only about 5 per cent of the energy required to extract aluminum from bauxite.

Table 6. Estimated world production of bauxite in 1976

	Production (millions of tonnes)
Australia	23.5
Guinea	11.3
Jamaica	10.3
Surinam	4.6
Guyana	3.1
Greece	2.7
France	2.3
United States	2.1
Other noncommunist countries	9.2
Total noncommunist countries	69.1
Communist countries	10.5
World total	79.6

Source: World Bureau of Metal Statistics, July 1977.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32910-1	Bauxite	free	free	free	free
35301-1	Aluminum pigs, ingots, blocks, notch bars, slabs, billets, blooms and wire bars	free	1¢ per lb	5¢ per lb	—
35302-1	Aluminum bars, rods, plates, sheets, strips, circles, squares, discs and rectangles	free	2¢ per lb	7.5¢ per lb	free
35303-1	Aluminum channels, beams, teas and other rolled, drawn or extruded sections and shapes	free	12½%	30%	free
35305-1	Aluminum pipes and tubes	free	12½%	30%	free
92820-1	Aluminum oxide and hydroxide; artificial corundum (this tariff includes alumina)	free	free	free	free

Tariffs (concl'd)

United States

Item No.		
417.12	Aluminum compounds: hydroxide and oxide (alumina)	free
601.06	Bauxite	free
618.01	Unwrought aluminum in coils, uniform cross section not greater than 0.375 inch	1.2¢ per lb
618.02	Other unwrought aluminum, excluding alloys	1¢ per lb
618.04	Aluminum silicon	1¢ per lb
618.06	Other aluminum alloys	1¢ per lb
618.10	Aluminum waste and scrap	0.7¢ per lb

Sources: For Canada, The Custom Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976) TC Publication 749.
Various tariffs are in effect on more advanced fabricated forms of aluminum.

Antimony

G.R. PEELING

Canada's production of antimony is derived as a byproduct of lead smelting operations, principally in the form of antimonial lead, but also as an antimonial dross and, in much smaller quantities, as high-purity antimony metal. The value of the antimony content of primary antimonial lead produced in 1976 was $1 370 000 compared with $1 467 928 in 1975. The value of antimony contained in ores and concentrates produced in 1976 was $5 900 000 compared with $5 900 912 in 1975. The quantity of antimony contained in ores and concentrates, as reported by Statistics Canada, is withheld to protect the confidentiality of the producer.

Imports of antimony oxide in 1976 totalled 734 321 kilograms, of which Britain supplied 84 per cent, the United States 12 per cent and Belgium and Luxembourg 4 per cent. Regulus (metal) import statistics were discontinued in 1964.

Cominco Ltd., which operates a lead smelter and refinery at Trail, British Columbia, is the main producer of primary antimonial lead in Canada. Its antimonial lead has a variable antimony content up to 23 per cent, depending on customer's requirements. Cominco produced 447 tonnes* of antimony contained in an 18 per cent antimonial lead in 1976 compared with 364 tonnes in 1975. The only other primary producer of antimonial lead is Brunswick Mining and Smelting Corporation Limited, Smelting Division, which operates a lead plant at Belledune, New Brunswick. The company produced 262 tonnes of antimony contained in a slag in 1976 compared with 61 tonnes of antimonial lead containing 10 per cent antimony in 1975. Secondary smelters recovered antimonial lead from scrap metal but no recent information is available concerning this production.

Domestic sources and occurrences

Most of the antimonial lead produced at Trail is a byproduct of the lead concentrate obtained from ores of Cominco's Sullivan mine at Kimberley, British Columbia. Other sources are the lead-silver ores and concentrates shipped to Trail from other Cominco mines and from custom shippers. The lead bullion produced from the smelting of these ores and concentrates contains about one per cent antimony, which is recovered in anode residues from the electrolytic refining of the lead bullion, and in furnace drosses produced during purification of the cathode lead. These residues and drosses are treated to yield antimonial-lead alloy, to which refined lead may be added to produce marketable products of the required grade. At Belledune, the Brunswick Mining and Smelting plant recovers antimonial lead alloys of whatever grade the market demands.

Consolidated Durham Mines & Resources Limited operates Canada's only antimony mine. It mines low-angle dipping veins containing stibnite, Sb_2S_3, at its Lake George property near Fredericton, New Brunswick. During the year, shaft sinking was completed from the 165-metre level to the 210-metre level and the level station was cut. The mill, with a capacity of 360 tonnes a day, treated about 82 000 tonnes of ore to produce over 4 000 tonnes of concentrate grading 65 to 66 per cent antimony. Concentrates are shipped to Belgium, Italy, France and the United States. At the end of June, 1976, reserves were 417 300 tonnes grading 4.58 per cent antimony, sufficient to continue operating at current levels for another four and a half years. In 1975 the company undertook a feasibility study of constructing an antimony smelter-refinery complex at the minesite. Initial capital costs were reported as $7 million but in 1976 were upgraded to $8 to $10 million. The company reports that for such an investment to occur, reserves, at current operating rates, must be a minimum 10 years. Consequently, the company has decided to emphasize on-property exploration at Lake George where only 1 800 of the 6 200 acres of holdings have been explored to date (June 30, 1976).

Equity Mining Corporation is continuing exploration of its silver-gold-copper-antimony property near Houston, British Columbia. The property is owned 70 per cent by Equity and 30 per cent by Kennco Explora-

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

tions (Western) Limited and reserves are given as 39.5 million tonnes grading 0.33 per cent copper, 95 grams of silver, 0.89 grams of gold and 0.82 per cent antimony a tonne. Bench scale studies indicate that the antimony can be extracted from the concentrates and that the antimony could be an important byproduct. Equity announced in late-1976 that negotiations for senior financing were under way and if negotiations were completed by the spring of 1977 the property might be in production by mid-1978 at the rate of 4 000 tonnes a day and at a cost of $40 to $50 million.

Con-Am Resources Ltd. announced that their Carbon Hill antimony property near Whitehorse in the Yukon Territory would be subject to a preliminary feasibility study. The property was owned and developed in the period 1964 to 1967 by the Yukon Antimony Corporation Ltd. Reserves of 127 000 tonnes grading 4 per cent antimony were established by Yukon Antimony and a mill test established that a 60.7 per cent antimony concentrate could be produced at a 93 per cent recovery level. Con-Am hopes to confirm the reserves and milling results with a view to eventually

Table 1. Canada, antimony production, imports and consumption, 1975-76

	1975		1976p	
	(kilograms)	($)	(kilograms)	($)
Production				
Antimonial lead alloy	364 046	1 467 928	375 000	1 370 000
Antimony in ores and concentrates	. .	5 900 912	. .	5 900 000
Total	. .	7 368 840	. .	7 270 000
Imports				
Antimony oxide				
United Kingdom	366 911	1 281 000	614 346	1 851 000
United States	27 170	100 000	86 228	305 000
Belgium-Luxembourg	—	—	33 747	100 000
People's Republic of China	998	3 000	—	—
Total	395 079	1 384 000	734 321	2 256 000

	1974			1975		
	Antimony regulus[1]	Antimonial lead alloy[2]	Total	Antimony regulus[1]	Antimonial lead alloy[2]	Total
	(kilograms)			(kilograms)		
Consumption[3]						
Antimony used for, or in the production of:						
Antimonial lead	795 019	. . .	795 019	348 231	. . .	348 231
Babbitt	45 415	8 099	53 514	32 768	11 802	44 570
Batteries	. . .	1 072 048	1 072 048	. . .	577 200	577 200
Solder	53 731	2 786	56 517	21 062	10 716	31 778
Type metal	12 963	111 584	124 547	20 232	123 437	143 669
Other commodities	76 657	2 288	78 945	31 871	- -	31 871
Total	983 785	1 196 805	2 180 590	454 164	723 155	1 177 319
Held by consumers on December 31[3]	79 142	240 963	320 105	116 760	170 478	287 238

Source: Statistics Canada.
[1]Antimony metal. [2]Antimony content of primary and secondary antimonial lead alloys. [3]Available data, as reported by consumers.
pPreliminary; . . Not available; — Nil; . . . Not applicable.

putting the property into production by early 1978 at a mill rate of 180 tonnes a day and at an estimated cost of $500 000. The company also reports that negotiations are being conducted with a possible concentrate buyer in Japan.

World Review

Modest recovery in 1976 from the recession that gripped most major industrial economies from late 1974 through 1975 resulted in higher levels of demand for most antimony products, a decline in stocks held by producers in the United States, and improved prices for ore, metal and oxide. However, the overall tenor of the market remained soft and consumption and production levels are still well below the 1973 and 1974 levels. The battery sector enjoyed an excellent year in the United States as sales increased 17.6 per cent over 1975 to a level of 60.7 million units, both original installation and replacement. The severe winter conditions in North America and Europe led to the improved demand for batteries and thus for antimonial lead. Oxide consumption in flame retardants also improved, particularly in Britain.

World mine production of antimony as estimated by the United States Bureau of Mines declined 7.6 per cent in 1976 to 70 003 tonnes compared with 75 725 tonnes in 1975. This decline resulted from strikes and production problems of a technical nature at several major producers.

Antimony is produced from ores and as a smelter byproduct in about 25 countries. The major sources of ore are the Republic of South Africa, the People's Republic of China, Bolivia, U.S.S.R., Thailand, Mexico, Canada and Yugoslavia. Prior to 1935, China, which reputedly has over 50 per cent of the world's reserves, produced two-thirds of the annual world output of antimony, but during the Chinese-Japanese War the centre of production shifted to the Americas. The United States, Mexico and Bolivia were the leading world suppliers of antimony during and immediately after The Second World War. In the years following the Korean War, South Africa, China and Bolivia became the major suppliers.

Republic of South Africa. Consolidated Murchison Limited operates the world's largest antimony mine near Gravelotte in northern Transvaal. The company milled 642 800 tonnes of ore in 1976 compared with 637 000 tonnes in 1975. Although ore milled increased, saleable concentrate output decreased by 6 800 tonnes to a level of 18 341 tonnes because of lower-grade ore and because operations continue to be plagued by high arsenic contents in some concentrates, and this product is presently being stockpiled. High arsenic concentrate production increased from 1 954 tonnes in 1975 to 3 849 tonnes in 1976. A pilot plant is being built to leach the arsenic from the concentrates and, if successful, will be expanded to treat current production and stockpiled material. Production from the new Athens shaft has been delayed by ground problems not revealed by exploratory drilling. Exploration drilling for new ore at the Alpha shaft is focusing on a potential reef zone 300 metres below present workings. The company also examined a nearby occurrence of antimony-bearing outcrop but it proved of no economic

Table 2. Canada, consumption and consumers' stocks of antimony[1], 1967-76

	Consumption			On hand at end of year		
	Antimony regulus[2]	Antimonial lead alloy[3]	Total	Antimony regulus[2]	Antimonial lead alloy[3]	Total
		(kilograms)			(kilograms)	
1967	539 856	1 132 181	1 672 037	. .	. .	. .
1968	530 536	963 840	1 494 376	170 249	66 863	237 112
1969	592 275	1 053 137	1 645 412	236 689	68 957	305 646
1970	518 007	635 212	1 153 219	131 501	91 563	223 064
1971	672 007	986 602	1 658 609	107 494	92 790	200 284
1972	919 114	983 762	1 902 876	125 983	125 180	251 163
1973	444 323	963 041	1 407 364	156 091	258 649	414 740
1974	983 785	1 196 805	2 180 590	79 142	240 963	320 105
1975	454 164	723 155	1 177 319	116 760	170 478	287 238
1976	. .	. .	. .	. .	. .	. .

Source: Statistics Canada.
[1]Available data, as reported by consumers. [2]Antimony metal. [3]Antimony content of primary and secondary antimonial lead alloys.
. . Not available.

importance. Reserves are sufficient for eight more years of operation at current production levels. About a third of the mine's output is converted to crude oxide at the nearby Antimony Products (Proprietary) Limited plant. This plant is owned 50 per cent by Consolidated Murchison and 50 per cent by Chemetron Corporation, a United States - based company that purchases a large share of the plant's output.

Bolivia. A new antimony smelter, located at Vinto, just south of Oruro in central Bolivia, was comissioned in September 1975 but normal production levels were not achieved until early in 1976. The plant, operated by the state mining company Empresa Nacional de Fundiciones (ENAF), has an annual capacity of 5 000 tonnes of 99.6 per cent metal and 1 000 tonnes of antimony trioxide. The capital cost of the plant was given as $17.5 million in U.S. currency. The major portion of the feed for the smelter comes from the Chilcobija mine. ENAF entered into a contract with Derby and Co. Ltd., an affiliate of Philipp Brothers Division of Engelhard Minerals & Chemicals Corporation, in 1976 whereby Derby became the marketing agent for ENAF's antimony in the United States.

Table 3. Canada, consumption of antimony regulus and antimonial lead alloy, 1965, 1970, 1974-76

	Antimony regulus[1]	Antimonial lead alloy[2]
	(kilograms)	
1965	299 425	1 259 748
1970	518 385	635 676
1974	983 785	1 196 805
1975	454 164	723 155
1976	. .	. .

Source: Statistics Canada.
[1]Consumption of antimony regulus (metal) as reported by consumers. Does not include antimony in antimonial lead produced by Cominco Ltd. [2]Antimony content of primary and secondary antimonial lead alloys.
. . Not available.

Thailand. Mine production of antimony concentrates has been on the decline since 1974 when production of 5 780 tonnes was reported by the World Bureau of Metal Statistics. Production at the Banpin property of Hibino Metal Industry Company, a Japanese company, suffered technical problems which kept output in 1976 below the rated capacity of 150 tonnes of concentrate a month. Hibino is also involved in a property near Chiang Mai and plans to produce about 100 tonnes a month of concentrate grading 60 per cent antimony, commencing in March 1977. The Phadad open-pit mine, closed in 1973, was reopened in the last half of 1976 as an underground operation by the Phluang Thong Thai Co., an affiliate of the Hochschild group. Initial production is planned at a rate of 150 tonnes a month of hand-cobbed and gravity concentrates. A flotation plant is planned for late-1977. Most of the mine's output is scheduled to go to an oxide plant in France operated by Société Industrielle et Chimique de l'Aisne Migest Freres (SICA).

Mexico. Scurry-Rainbow Oil Limited has constructed an antimony plant at its Santa-Rita mine in the state of Zacatecas. The plant came on stream in 1976 but heavy rains and power problems prevented continuous operation during the year. The mine has a mill capacity of 100 tonnes of ore a day. Reserves on April 1, 1977 were 150 810 tonnes grading 3.02 per cent antimony with substantial amounts of lead, zinc and silver. The plant capacity is approximately 750 tonnes of metal a year.

Yugoslavia. Discovery of additional ore reserves has led to the reopening of the former Lojane mine on Mt. Kopaonik in Serbia. Trial production started in the last half of 1976. The planned production level is 40 000 tonnes of ore a year to produce about 2 000 tonnes of concentrate a year. The mine has reserves for 20 years of operation at this rate but production may eventually rise to 270 000 tonnes of ore annually if future expansion plans are realized.

Turkey. An Italian engineering firm, Tecnomin, has won a contract from a private company, Ozdemur Antimuan Madenleri A/S to construct a 2 600-tonne-a-year antimony smelter and refining complex at an estimated capital cost of $10 million U.S. Work was to commence in late-1976 for completion in two years' time. Tecnomin is an affiliate of the Italian state-owned Ente di Gestione per le Aziende Minerarie Metallurgiche (EGAM). Another EGAM affiliate, Comemin, will act as agent in the promotion of worldwide sales of Turkish antimony metal and oxide.

Australia. The Blue Spec gold-antimony mine at Nullagine, owned by Mulga Mines Pty. Ltd., was reopened in early-1976 and by November had reached the planned production level of 5.8 tonnes a day of 60 per cent-grade antimony concentrate. Reserves are given as 80 000 tonnes grading 4.63 per cent antimony and 45.14 grams of gold a tonne. Diamond drilling below the known limits of the ore zone has intersected additional mineralization, and the scope for development of more reserves appears excellent.

United States. N L Industries, Inc. operates the world's largest antimony smelter for ores and concentrates at Laredo, Texas, producing antimony metal and oxide, mainly from imported Mexican, Bolivian and South African ores. The United States' mine production of antimony in 1976 was estimated to be 240 tonnes, a 70 per cent decrease from the 1975 level of 804 tonnes and the lowest level of mine production since 1930. The Sunshine Mining Company which operates the Sunshine mine in the Coeur d'Alene district of Idaho is one of the major mine producers of antimony in the U.S. but a strike closed the mine from March 11, 1976 through year-end.

Primary smelter production was 13 247 tonnes, a 20 per cent increase from the 11 058 tonnes of antimony material produced in 1975. Secondary production was little changed as output was 16 329 tonnes and 16 297 tonnes in 1976 and 1975, respectively. Imports of ores and concentrates, metal and oxide increased in 1976 as the total of imports in all categories showed an increase of 17 per cent to 19 797 tonnes from the 1975 level of 16 970 tonnes. Imports of ores and concentrates from Canada jumped 71 per cent in 1976 to a level of 989 tonnes (antimony content) and established Canada as the fourth largest supplier to the United States in this category. Consumption of all types of antimony dropped 7 per cent to an estimated level of 26 127 tonnes in 1976.

Table 4. World mine production of antimony, 1974-76

	1974	1975	1976[e]
	(tonnes)		
Republic of South Africa	15 162	16 211	15 422
People's Republic of China	15 000	15 000	
Bolivia	12 626	13 967	13 608
U.S.S.R.	7 500	7 500	. .
Thailand	5 780	4 276	. .
Mexico	2 407	3 137	3 175
Canada	2 500	2 600	
Yugoslavia	2 208	2 136	2 177
Turkey	3 350	1 930	. .
Australia	1 406	1 542	. .
Morocco	1 850	1 052	. .
Italy	1 177	1 028	. .
Guatemala	800	900	. .
United States	600	804	240
Czechoslovakia	750	750	. .
Other countries	2 853	2 892	35 381
Total	75 969	75 725	70 003

Sources: World Metal Statistics, March 1977 for 1974 and 1975, and U.S. Bureau of Mines Commodity Data Summaries, January 1977 for 1976.
. . Included in "Other countries"; [e]Estimated.

The new $7.5 million antimony recovery plant being built by ASARCO Incorporated at El Paso, Texas is scheduled for completion by mid-1977. The plant will have the capacity to produce 1 650 tonnes of 99.5 per cent pure antimony metal a year and will employ between 25 and 30 people. The production will be based on copper-silver-antimony concentrates from mines in the Coeur d'Alene district of Idaho. The U.S. Antimony Corporation, in a joint venture with the Bolivian firm Impressa Minera Bernal Hermanos S.A., completed a smelter expansion program with the addition of a trioxide unit at its Thomsons Falls, Montana plant. The construction of a 3 175-tonne-a-year unit was completed in August 1976. The company now produces low-grade battery metal, high-purity antimony, antimony trioxide and sodium antimonate.

In October the Federal Preparedness Agency set a new government stockpile goal of 18 260 tonnes (the previous goal was zero). There were no shipments from the stockpile in 1976 and 36 922 tonnes remained on hand at year-end.

Table 5. Industrial consumption of primary antimony in the United States, by class of material produced

Product	1974	1975	1976[e]
	(tonnes, antimony content)		
Metal Products			
Ammunition	110	217	57
Antimonial lead	6 578	4 144	3 012
Bearing metal and bearings	432	365	288
Cable covering	14	21	18
Castings	28	16	—
Collapsible tubes and foil	16	8	22
Sheet and pipe	63	54	60
Solder	186	121	87
Type metal	97	68	50
Other	122	109	36
Total	7 646	5 123	3 630
Nonmetal Products			
Ammunition primers	10	13	7
Fireworks	10	9	7
Flameproofing chemicals and compounds	3 976	3 446	2 730
Ceramics and glass	1 256	897	942
Pigments	417	291	245
Plastics	1 298	990	621
Rubber products	603	416	152
Other	1 150	597	1 085
Total	8 720	6 659	5 789
Total reported	16 366	11 782	9 419
Grand Total	16 366	11 782	12 732[1]

Sources: U.S. Bureau of Mines, *Minerals Yearbook* Preprint 1975 and Mineral Industry Surveys.
[1]Estimated 100 per cent coverage based on reports from respondents that consumed 70 per cent of the total antimony in 1975.
[e]Estimated; — Nil.

Uses

Antimony is used principally as an ingredient in many alloys and in the form of oxides and sulphides.

Antimony hardens and strengthens lead and inhibits its chemical corrosion. The use of antimonial lead in storage batteries remains its major outlet, but due to technological developments the antimony content in batteries has been progressively reduced in recent years, from about 12 per cent to current levels which vary from 3 to 6 per cent of the antimonial lead contained. The battery market is in a state of flux and the use of antimony in this sector is likely to decline substantially over the next 5 to 10 years as usage of substitute materials increases. The major competitor to antimonial lead used in the manufacture of battery grids is an alloy of calcium-tin-lead.

Antimonial lead alloys are also used for power transmission and communications equipment, printing metal, solder, ammunition, chemical pumps and pipes, tank linings, roofing sheets and antifriction bearings.

Antimony oxide, Sb_2O_3, usually produced directly from highgrade sulphide ore, is used extensively in plastics and in flameproofing compounds, the most important growth area in antimony consumption.

Antimony trioxide or trichloride in an organic solvent has long been recognized as having significant flame-retardant properties and is now used extensively in carpets, rugs and carpet underlay. The trioxide is also a glass-former, and is sought for its ability to impart hardness and acid resistance to enamel coverings for bathtubs, sinks, toilet bowls and refrigerators. Sodium antimonate is used in the production of high-quality glass and has a growing use in the manufacture of television screens. The pentasulphide, Sb_2S_5, is used as a vulcanizing agent by the rubber industry. Burning antimony sulphide creates a dense white smoke that is used in visual control, in sea markers and in visual signaling.

Antimony is valuable for paint formulation since its high hiding power and various chemical compounds produce a wide range of pigments. High-purity metal is used by manufacturers of indium-antimony and aluminum-antimony intermetallic alloys as a semiconductor in transistors and rectifiers.

Outlook

The modest recovery experienced by antimony in 1976 is likely to continue through 1977 as most western world economies enjoy improved conditions but demand is still not likely to achieve the levels of 1973-74.

There are two major counter-balancing trends affecting the consumption of antimony. On the negative side, the traditional use of antimonial lead in battery grids is on the decline as alternative alloys which possess better performance standards enter the market. The major alloys competing with antimonial lead are: calcium-tin-lead, strontium-tin-lead and a new combination of cadmium-antimony-lead in the positive grid and calcium-tin-lead in the negative grid. These alloys are being used in batteries that are termed "maintenance free" as they come completely sealed and do not need topping-up with water. The antimonial lead producers have responded with what is termed a "low-maintenance" battery alloy composed of 2.5 to 3.0 per cent antimony (normal antimony lead battery alloys run about 4.5 to 6.0 per cent antimony). Approximately 60 per cent of battery sales in the United States in 1976 were of a kind containing a 4.5 to 6.0 per cent antimony alloy, 29 per cent of low-maintenance alloy and 11 per cent maintenance-free. Extrapolating a growth rate in battery sales of 4.0 per cent from 1970 to 1980 in the United States and then applying a market share breakdown in 1980 of 70 per cent maintenance-free and 30 per cent low-maintenance and normal antimony content, the consumption of antimony in the manufacture of antimonial lead grids could decline by as much as 50 to 70 per cent. This will leave a substantial amount of antimony in the form of unsaleable antimonial lead in the hands of the secondary refiners by 1980. As yet, the secondary lead producers do not have the technology to extract the antimony and produce oxide, a much more saleable product. It appears that the secondary producers could go through a difficult economic and technological adjustment in the years ahead. All new automobiles will likely have the maintenance-free battery by 1980 as original installation equipment and this will be one of the leading spurs to the battery's acceptance. In Europe and Japan, the incursion of maintenance-free batteries in the market will occur more slowly with the major impact being felt in the early 1980s.

On the positive side, growth in the application of antimony trioxide as a flame retardant is expected to be between 10 and 15 per cent per annum through 1980 and this will partially offset the decline in the battery sector. Government legislation continues to play a large role in expanding the demand for flame retardants. Flameproofing regulations now apply in the United States to children's sleepwear, automobile upholstery, bedding products, carpet fibres and underlays, plus numerous other textile items. Government legislation in Europe in this regard is also becoming increasingly common.

Another trend which has been evident in the 1970s is the increasing forward integration of the mine producers into the smelting and refining of their ore into metal and oxide. This has resulted in substantial changes in the historic distribution pattern of ores and concentrates. New smelters have been built recently in Bolivia, South Africa and the United States and new smelters are being built in Mexico and Turkey. These developments have moved good-grade antimony ore away from existing non-integrated smelters and forced them to rely on output from smaller, lower quality and less reliable producers. Thus in recent years 60 per cent antimony concentrates have commanded a premium price.

In 1977 economic conditions are expected to show a modest improvement. Ore and oxide prices are expected to show some improvement, with perhaps a 5 to 10 per cent price increase by year-end 1977. The outlook for metal and alloy is bearish, with stocks expected to remain high and prices weak. The impact of the maintenance-free battery will be felt mainly in North America in the 1977 to 1980 period, with inroads into the European market taking place in the early 1980s. Consequently, the market for metal during this period may be unstable as producers and consumers adjust to new circumstances. Also, the availability of borates as a substitute product for antimony trioxide in the manufacture of flame retardants will act as a damping factor on upward price movements for oxide. The supply-demand picture for antimony is now in a major period of change which is likely to last through the early 1980s and which makes prediction of market developments with any degree of confidence extremely difficult.

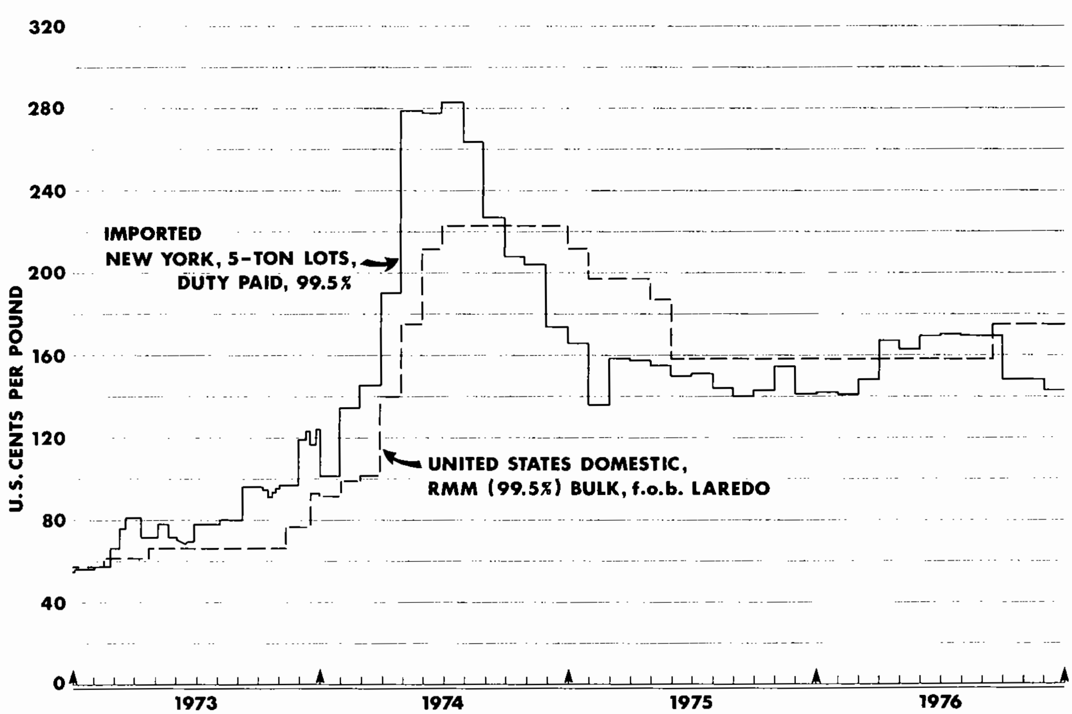
Prices

Antimony metal prices as quoted by producers in North America were steady for most of the year with metal and trioxide prices increasing in the fourth quarter. Ore prices in the United States market improved steadily during the year. After opening in January at $17 to $18.50 a short ton unit (stu) for 60 per cent lump ore, the price increased steadily to close the year in a range of $23.50 to $25 per stu.

The United States domestic price of antimony (RMM brand) as quoted in *Metals Week,* in bulk, 99.5 per cent Sb, fob Laredo, Texas, was $1.58 a pound in January. It remained unchanged until September 16 when a new quote of $1.75 a pound was established. The price of Lone Star brand (99.8 per cent Sb) opened the year at $1.90 and was increased on September 16 to $2.10 a pound.

The European free market metal price (99.6 per cent Sb, 1 tonne lots, cif Europe) opened the year at £1 500 to £1 600 a tonne. This price increased during the first half of the year and peaked in July at £2 350 a

ANTIMONY METAL PRICES



Source: METALS WEEK

tonne. Thereafter the price weakened and ended the year in the £1 500 range. From December of 1976 the European price, as quoted by United Kingdom dealers, switched to United States currency because of new exchange control regulations imposed by the Bank of England.

Tariffs

Canada

Item No.		British Preferential	GSP[1]	Most Favoured Nation	General
33000-1	Antimony, or regulus of, not ground, pulverized or otherwise manufactured	free	free	free	free
33502-1	Antimony oxides	free	free	12½%	25%

United States

TSUS No.		British Preferential	GSP[1]	Most Favoured Nation	General
601.03	Antimony ore		free	free	
632.02	Antimony metal, unwrought (duty on waste and scrap temporarily suspended)		1¢ per lb. or free	1¢ per lb.	

European Economic Community (EEC)

Brussels Tariff Nomenclature No.		British Preferential	GSP[1]	Most Favoured Nation	General
26.01	Antimony ore		free	free	
81.04	I. Antimony, unwrought; waste and scrap		8%	8%	
	II. Other antimony		8%	8%	

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States Annotated (TSUS); *Official Journal of the European Communities.*
[1]GSP — Generalized System of Preferences extended to all, or most, developing countries.

Asbestos

G.O. VAGT

Production problems that affected most of the Quebec asbestos industry in 1975 were overcome and asbestos fibre shipments substantially increased in 1976. As a result, shipments approached 1974 levels and would probably have been greater if additional capacity had been available to serve the strong demand for most grades of fibre. Development of fibre supply in Canada and other parts of the world has not kept pace with the strong growth in consumption, mainly because of increased demand in the developing countries.

Canadian production (shipments)

Canadian production of asbestos fibre in 1976 was 1 549 000 tonnes* valued at $445 523 000 compared with 1 055 667 tonnes valued at $267 246 000 in 1975. Approximately 85 per cent of total production is from Quebec, 5 per cent each from British Columbia and the Yukon Territory, 4.5 per cent from Newfoundland and less than 1 per cent from Ontario.

Canada exported nearly 95 per cent of its total production of asbestos fibre to more than 70 countries. Exports totalled 1 467 018 tonnes in 1976, with nearly 80 per cent of the total distributed among the following 10 countries; United States, 37.9; Japan, 9.9; West Germany, 9.1; United Kingdom, 6.4; France, 3.8; Australia, 3.3; Belgium and Luxembourg; 2.5; Spain, 2.4 and Mexico, 2.0. This quantity provides the noted percentage of total asbestos imports: United States, 96 per cent; European Economic Community (EEC), 57 per cent; Japan, 39 per cent; Eastern Europe, 7 per cent and others, 54 per cent.

The value of Canadian exports of manufactured asbestos products in 1976 was $14 874 000 compared with $15 877 000 in 1975, according to Statistics Canada. The value of imports of manufactured asbestos products was $20 530 000 in 1976 compared with $23 815 000 in 1975.

Canadian developments

Developments at the asbestos-producing mines in Canada are highlighted in Table 2. Production at the new mine of United Asbestos Inc. in Midlothian township, Ontario was slowed by technical problems and environmental control difficulties that prevented United from complying with Ontario's relatively strict new standards of two fibres per cubic centimetre* per eight-hour average. Operations proceeded at from 30 to 40 per cent of capacity and this relatively low rate contributed to default in financial commitments and eventual receivership of the company in March 1977. Capital costs to production were nearly $42 million as of March. The mill is designed to process 3600 tonnes of ore a day and produce 90 000 tonnes of asbestos fibre a year. Estimated ore reserves are 27 million tonnes with an average fibre content of 7.5 per cent.

Canadian Johns-Manville Company, Limited intends to spend over $60 million of an allotted $77 million on an expansion program over the next five years. Initially, funds will be provided for property acquisition and the construction of mine buildings. As a result of the November 1976 election victory by the Parti Quebecois in Quebec, the planned investment program was delayed for a short period because there were uncertainties concerning policies of the new government in relation to the asbestos industry. An independent study to be completed in late 1977 by the Quebec government is designed to evaluate opportunities for the optimum development of the industry in Quebec.

Asbestos Corporation Limited will mine and beneficiate the King-Beaver open-pit ore and transport this ore to the Normandie mill for processing. Normandie mine ore will be exhausted during 1977. Non-beneficiated underground ore from the King-Beaver mine will continue to be milled at the British Canadian plant. The results of an underground development program started in 1975 at Asbestos Hill continued to be evaluated during 1976.

Cassiar Asbestos Corporation Limited completed a waste-removal program and continued footwall stabilization and open-pit improvement programs at Cassiar, British Columbia. Also, work continued on a

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

*Two fibres greater than five microns in length over an eight-hour period.

Table 1. Canada, asbestos production and trade, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
By type				
Crude, groups 1, 2 and other milled	5	16 000	. .	. .
Group 3, spinning	23 098	24 996 000	. .	. .
Group 4, shingle	329 890	132 058 000	. .	. .
Group 5, paper	127 591	36 063 000	. .	. .
Group 6, stucco	173 085	32 135 000	. .	. .
Group 7, refuse	401 892	41 974 000	. .	. .
Group 8, sand	106	4 000	. .	. .
Total	1 055 667	267 246 000[1]	1 549 000	445 523 000[1]
By province				
Quebec	801 972	176 942 624	1 263 000	343 164 000
Yukon	103 735	32 820 720	103 000	34 460 000
Newfoundland	57 867	18 139 165	86 000	33 383 000
British Columbia	76 771	37 849 743	71 000	30 719 000
Ontario	15 322	1 493 874	26 000	3 797 000
Total	1 055 667	267 246 126	1 549 000	445 523 000
Exports				
Crude				
United Kingdom	49	18 000	49	22 000
France	—	—	9	19 000
United States	93	5 000	22	15 000
Japan	41	22 000	3	6 000
Total	183	45 000	83	62 000
Milled fibre (groups 3, 4 and 5)				
United States	143 156	58 695 000	130 218	62 953 000
West Germany	102 269	38 236 000	98 717	42 610 000
United Kingdom	38 588	19 514 000	52 704	29 573 000
Australia	26 796	10 970 000	42 802	20 659 000
France	21 694	8 814 000	35 578	18 929 000
Japan	20 490	6 666 000	44 994	18 539 000
Belgium and Luxembourg	21 403	9 091 000	29 020	15 790 000
Spain	17 380	7 277 000	28 260	15 004 000
Italy	15 242	6 243 000	21 130	12 022 000
Mexico	25 351	12 122 000	22 415	12 019 000
India	11 365	5 263 000	17 457	9 500 000
Columbia	5 582	2 247 000	14 734	7 437 000
Other countries	115 646	46 636 000	164 581	82 821 000
Total	564 962	231 774 000	702 610	347 856 000

Table 1. (cont'd)

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Shorts (groups 6, 7, 8 and 9)				
United States	315 160	39 979 000	426 243	62 301 000
Japan	43 057	7 057 000	100 473	20 472 000
West Germany	19 368	2 847 000	34 126	6 211 000
United Kingdom	28 507	3 642 000	41 169	5 932 000
Netherlands	19 856	2 447 000	32 667	4 511 000
South Korea	3 821	783 000	12 047	3 016 000
France	11 816	1 534 000	20 196	2 535 000
Thailand	2 746	515 000	8 594	1 972 000
Spain	4 671	848 000	7 568	1 589 000
Belgium and Luxembourg	11 463	2 034 000	7 134	1 589 000
Argentina	6 323	879 000	7 432	1 382 000
Mexico	3 894	684 000	6 666	1 289 000
Nigeria	816	168 000	5 160	1 244 000
Australia	3 243	499 000	5 975	1 045 000
Brazil	3 558	416 000	6 638	991 000
Other countries	31 163	5 984 000	42 237	8 698 000
Total	509 462	70 316 000	764 325	124 777 000
Grand total crude, milled fibres and shorts	1 074 607	302 135 000	1 467 018	472 695 000
Manufactured products				
Asbestos cloth, dryer felts, sheets				
United States		1 164 000		2 136 000
Australia		109 000		178 000
United Kingdom		163 000		30 000
Peru		—		12 000
Thailand		—		11 000
Japan		31 000		10 000
Other countries		972 000		46 000
Total		2 439 000		2 423 000
Brake linings and clutch facings				
United States		1 056 000		1 352 000
Ecuador		270 000		149 000
France		165 000		70 000
Hong Kong		33 000		44 000
Guatemala		30 000		14 000
Lebanon		34 000		14 000
Kuwait		7 000		13 000
Thailand		28 000		10 000
Iran		1 000		9 000
Other countries		284 000		65 000
Total		1 908 000		1 740 000

Table 1. (concl'd)

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Asbestos and asbestos cement building materials				
United States		4 226 000		4 934 000
Saudi Arabia		425 000		799 000
Spain		21 000		625 000
Iran		308 000		621 000
Netherlands		32 000		303 000
Iraq		264 000		178 000
Italy		—		160 000
United Kingdom		589 000		145 000
Peru		—		62 000
Other countries		1 540 000		240 000
Total		7 405 000		8 067 000
Asbestos basic products, nes				
United States		3 791 000		2 438 000
Cuba		—		74 000
France		97 000		38 000
Switzerland		71 000		35 000
United Kingdom		6 000		20 000
Australia		2 000		13 000
Barbados		—		9 000
Other countries		158 000		17 000
Total		4 125 000		2 644 000
Total exports, Asbestos manufactured		15 877 000		14 874 000
Imports				
Asbestos, unmanufactured	5 166	2 297 000	6 002	2 966 000
Asbestos, manufactured				
Cloth, dryer felts, sheets, woven or felted		3 824 000		2 842 000
Packing		1 837 000		1 599 000
Brake linings		5 947 000		4 513 000
Clutch facings		734 000		751 000
Asbestos-cement shingles and siding		179 000		143 000
Asbestos-cement board and sheets		841 000		337 000
Asbestos building materials, nes		7 696 000		7 336 000
Asbestos basic products, nes		2 757 000		3 009 000
Total Asbestos, manufactured		23 815 000		20 530 000
Total asbestos, unmanufactured and manufactured		26 112 000		23 496 000

Source: Statistics Canada.
[1] Value of containers not included.
[p] Preliminary; — Nil; nes Not elsewhere specified; . . Not available.

new mill air system and vacuum cleaning system. The Clinton Creek mine, Yukon Territory, is expected to close in 1978 because diamond drilling failed to upgrade reserves. A central vacuum system was installed in the mill to maintain average fibre counts within the currently required standards.

At the Advocate Mines Limited property in Baie Verte, Newfoundland, a program of conversion to larger mining equipment continued and the replacement of new crushing equipment was completed. Modifications to progressively improve dust control were also emphasized.

Prospective producers

Brinco Limited and ASARCO Incorporated began discussions that could lead to the development of the "A" asbestos deposit of Abitibi Asbestos Mining Company Limited. This property is located 84 kilometres north of Amos, Quebec. Capital costs to bring the project into production are presently estimated to be $300 million based on an annual output of 200 000 tonnes of fibre. Ore reserves in the "A" deposit are estimated at 100 million tonnes averaging 3.5 per cent asbestos fibre.

Rio Algom Limited continued evaluation of the deposit owned by McAdam Mining Corporation Limited. This property is situated approximately 32 kilometres east of Chibougamau, Quebec. McAdam and Campbell Chibougamau Mines Ltd. are jointly exploring an asbestos property in the same region, about 24 kilometres east of Chibougamau.

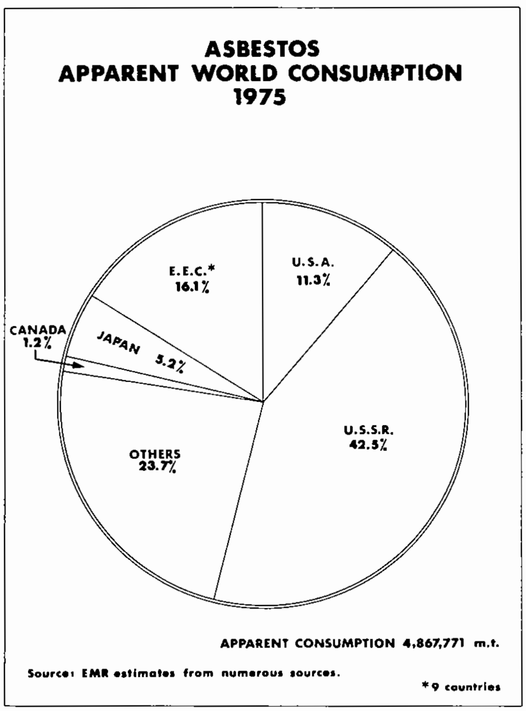
Algoma-Talisman Minerals Limited recently formed a joint venture with the Shield Development Company Limited to undertake exploration of an asbestos-bearing zone discovered in the Rush Lake-Horwood Lake area in Newton township, Ontario, about 105 kilometres southwest of Timmins, Ontario. Hollinger Mines Limited plans to evaluate an asbestos prospect on its Rundle Gold Mines Limited property, also in Newton Township, Ontario.

The Great Northern Pulp and Paper Group Ltd. is considering exploratory work on the former Nakhodas property in Deloro township, about 10 kilometres southeast of Timmins.

In northern British Columbia Cassiar expects to further evaluate the Kutcho Creek property situated near Dease Lake.

World production, and developments in major markets

Total world production of asbestos in 1976 was an estimated 5.3 million tonnes based on the inclusion of all grades from one to seven assumed to be recovered in the U.S.S.R. Chrysotile accounted for about 90 per cent of world production and the remaining production consisted of about 6 per cent crocidolite (blue asbestos) and 3 per cent amosite. Less than one per cent of other types of asbestos, including tremolite and an-



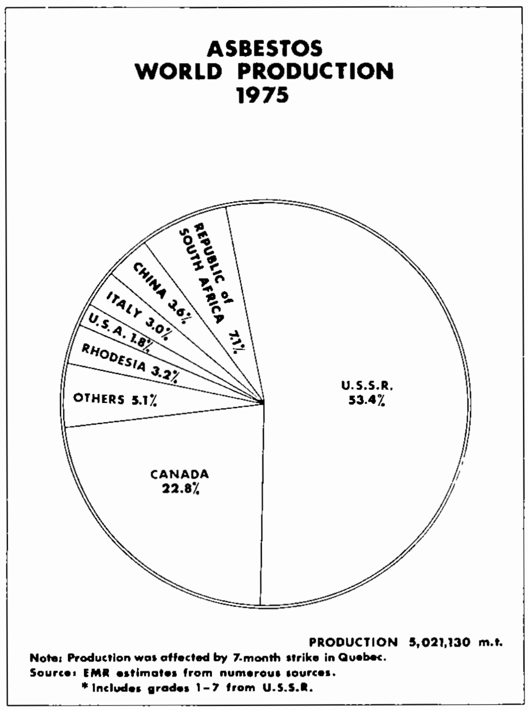


Table 2. Canadian asbestos producers and prospective producers, 1976

	Mine Location	Mill Capacity	Remarks
		(tonnes of ore/day)	
Producers			
1. Advocate Mines Limited	Baie Verte, Nfld.	6 800	Open-pit. Produces fibre equivalent Groups 4 and 6.
2. Carey-Canadian Mines Ltd.	East Broughton, Que.	5 000	Open-pit. Mainly produces Group 7 fibre.
3. Asbestos Corporation Limited			World's major independent asbestos producer.
Asbestos Hill mine	Putuniq, Que.	5 400	Annual rated capacity 270 000 tonnes of concentrate. Final processing to 90 000 tonnes of fibre following shipment to W. Germany.
British Canadian mine	Black Lake, Que.	11 200	Open-pit, two milling plants. Also processes underground ore from King Beaver mine.
King Beaver mine	Thetford Mines, Que.		Underground and open-pit. Mill closed by fire in December 1974.
Normandie mine	Vimy Ridge, near Black Lake, Que.	6 800	Open-pit. Mill will process K.B. open-pit ore when Normandie ore is depleted.
4. Bell Asbestos Mines, Ltd.	Thetford Mines, Que.	2 700	Underground.
5. Lake Asbestos of Quebec, Ltd.	Black Lake, Que.	8 200	Open-pit.
National Mines Division	Thetford Mines, Que.	3 200	Open-pit.
6. Canadian Johns-Manville Company, Limited			
Jeffrey mine	Asbestos, Que.	30 000	Open-pit; is western world's largest known asbestos deposit. Expanded complex designed to maintain annual output at a minimum of 540 000 tonnes of fibre.
7. Hedman Mines Limited	Matachewan, Ont.	300	Open-pit.
8. United Asbestos Inc.	Matachewan, Ont.	3 600	Open-pit; operated at 30% — 40% of capacity.
9. Cassiar Asbestos Corporation Limited			
Cassiar mine	Cassiar, B.C.	3 000	Open-pit. Two-month strike in July-August affected production.
Clinton mine	Clinton Creek, Yukon	3 600	Open-pit. Expected to close in 1978, when ore is exhausted. New mill air and vacuum cleaning system.
Prospective producers			
10. Abitibi Asbestos Mining Company Limited	Amos, Quebec	11 800	Feasibility study under way.
11. McAdam Mining Corporation Limited	Chibougamau, Quebec	4 500	Feasibility study under way.
12. Cassiar Asbestos Corporation Limited	Dease Lake, B.C.		Possible future development.

Source: Mineral Development Sector Department of Energy, Mines and Resources, Ottawa.

thophyllite, was produced, mainly in the United States.

The diagrams show a breakdown of 1975 world production and world consumption by country. Discrepancies occur in the data available from the U.S.S.R. and also in the interpretation of this data, resulting in problems of statistical correlation. Most of the annual output from the U.S.S.R. is consumed domestically although about 600,000 tonnes are exported, mainly to eastern European countries, Japan, France, West Germany and India.

Asbestos reserves in the U.S.S.R. are known to be very large and are probably greater than those in Canada. The three major producing areas in the U.S.S.R. are: the Bazhenovo deposits of the Central Urals, near Sverdlovsk, about 1400 km east of Moscow, where there is capacity of about 1.4 million tonnes a year of fibre; the Dzhetygara District, Northwest Kazakhstan, along the eastern flanks of the southern Urals, where a capacity of about 500 000 tpy is reported; Aktovrak, Tuva district, to the west of Lake Baikal, where an estimated 200 000 tonnes a year is produced. Progress continued at the new Kiembay deposit in the southern Urals where several Comecon countries are assisting in the completion of the project designed to produce 550 000 tonnes a year of asbestos. The Comecon countries are expected to receive most of the output from this new project.

The Republic of South Africa has the only commercial deposit of amosite and is also a major producer of crocidolite and chrysotile. Approximately 30 per cent of the country's total asbestos production of about 350 000 tonnes is chrysotile. Production was affected by political tensions and mining labour shortages. Also the shipping situation from southern Africa and Swaziland through the port of Maputo (formerly Lourenco Marques) continued to be a problem as a result of political upheavals in Moçambique.

Official figures for asbestos output have not been available from Rhodesia since the country's Unilateral Declaration of Independence in November, 1965 and subsequent imposition of United Nations (U.N.) trade sanctions. Rhodesia was the third largest producer of asbestos in the Western World, after Canada and Republic of South Africa, and the country undoubtedly remains a world-ranking producer with an estimated output of 300 000 tonnes a year.

Most United States production of approximately 110 000 tonnes a year is from California. Calaveras Asbestos Limited (formerly Pacific Asbestos Corporation, Limited) produced chrysotile grades 4 to 7 at Copperopolis, California. This operation re-opened in 1976 after its closure in 1974. Vermont Asbestos Group, Inc. is proceeding with expansion plans to extend the life of its mine at Belvedere Mountain, Vermont, which was purchased from GAF Corporation by an employee group in 1975. Annual output is about 35 000 tonnes of finished fibre.

Woodsreef Mines Limited, N.S.W., Australia, maintained output in 1976 while carrying out mill and crusher modifications designed to increase production capacity to 100 000 tonnes of fibre a year.

Pilot plant tests continued at Zidani, near Kozani, Greece. A 50 000 tonne-a-year plant is planned, with an ultimate annual capacity of 100 000 tonnes by 1980. Cerro Corporation is no longer a partner with the government in this venture.

A company in Turkey has plans to establish a new mine near Mihaliccik which would produce 10 000 tonnes of chrysotile a year and have expansion capabilities to 30 000 tonnes a year. Other asbestos projects in various stages of development are under way in Colombia, Brazil, Mexico and the Sudan. A property owned 70 per cent by Eternit Colombianos S.A. is being developed in Colombia by Asbestos Colombianos S.A. with plans for production of 18 000 tonnes of chrysotile a year. In Brazil the chrysotile asbestos mine at Cana Brava, which presently produces over 60 000 tonnes of fibre a year, is projected to produce 105 000 tonnes a year by 1979. In Mexico, Compania Minera Pegaso S.A., continued development of a chrysotile deposit in the Quicatlan District northwest of Oaxaca. Approximately 50 000 tonnes of fibre a year are to be produced in 1978. In the Sudan, Johns-Manville Corporation and Gulf International Corporation, together with the Sudanese government, are evaluating reserves of unspecified category that total 60 million tonnes.

Fibre groups, uses and technology

To evaluate the quality of asbestos fibre there are five basic properties which must be considered: fibre length distribution, fibre bundle diameter distribution, harshness, tensile strength and surface activity. Other properties governing quality are iron content, colour and dust content. The major standard on a length basis is that developed by the industry in Quebec, whereby asbestos is classified and priced by groups from the longest fibre, corresponding to No. 1, to the shortest, No. 9. Because there are more than 3000 uses for asbestos, it is more appropriate to classify the groups in categories and describe the major purposes the fibres serve than to list the products in which they are used.

Long fibres, Crudes Nos. 1 and 2 and Group 3: used in the textile industry, as electrical insulation, as a filtration medium and as reinforcing fillers in asbestos-cement products where great strength is required.

Medium-length fibres, Groups 4,5,6: reinforcing fillers in asbestos-cement products, friction materials such as brake linings and clutch facings, paper and pipe coverings.

Short fibres, Groups 7,8,9: reinforcing fillers in plastics, floor tile, asphalt, and in paints and oil-well muds.

A breakdown of United States asbestos demand is as follows: asbestos cement construction products, 37.4 per cent; flooring products, 18.1 per cent; friction products, 9.5 per cent; roofing products, 9 per cent; paper products, 7.4 per cent; packing and gaskets, 3.4

per cent; textiles, 2.4 per cent; insulation, 1.7 per cent and others, 11.1 per cent.

A world-wide trend continued during 1976 to stricter environmental control in the asbestos industry and to stricter legislation regarding the use of certain types of asbestos and asbestos products. In the United States, in July, the Occupational Safety and Health Administration (OSHA), under the U.S. Department of Labour, limited all occupational exposure to asbestos to two fibres per cubic centimeter of air in a time-weighted eight-hour average. This was a lowering from the old standard of five fibres per cubic centimeter that was effective since 1972. A proposed new regulation under discussion would lower the level to 0.5 fibres per cubic centimeter in a time-weighted eight-hour average.

A national asbestos emission standard in Canada that will specify the maximum dust that may enter the atmosphere surrounding mining operations and milling plants is being developed by Environment Canada. Initially, standards will apply to crushing, drying, milling and storage. In-plant emission standards are a provincial concern and these are being enforced in Ontario (2 fibres/cc) and in British Columbia (5 fibres/cc). Regulations are expected to become effective in Quebec, Newfoundland and the Yukon Territory in 1978.

The final report of the Beaudry Study Committee on health and environmental aspects of the asbestos industry in Quebec was released in the Quebec National Assembly on October 29. The Committee, headed by Judge Beaudry, was created June 18, 1975 and held the same powers and privileges as a Commission of Inquiry. It is anticipated that recommendations will be far-reaching as the Committee has the mandate to advise the government on the regulation of allowable asbestos levels in the workplace.

A report by the Asbestosis Working Group, a subcommittee on environmental health comprised of federal and provincial government health authorities, made recommendations concerned with smoking, medical surveillance of workers, protective clothing and respiratory devices, work practices, warning labels and the establishment of an exposure limit of two fibres per cubic centimetre over an eight hour time-weighted average. Also, it was recommended that authorities give consideration to stringent control of crocidolite.

Proposed regulations on asbestos transportation and use in Canada are expected to be released under the Hazardous Products Act by the federal departments of Health and Welfare and Consumer and Corporate Affairs. Industry has been alerted to the fact that the impending regulations could ban the importation of crocidolite. Certain consumer products containing free asbestos fibres have been banned since 1975. The sale of non-consumer products containing asbestos would also be regulated by identifying shipments with labels to help assure safe handling and usage.

Table 3. Canada, asbestos production and exports, 1965, 1970, 1974-76

	Crude	Milled	Shorts	Total
		(tonnes)		
Production[1]				
1965	148	598 377	660 840	1 259 365
1970	6 579	668 629	832 210	1 507 418
1974	19	759 907	883 837	1 643 763
1975	5	480 579	575 083	1 055 667
1976[p]	. .	. .	. .	1 549 000
Exports				
1965	112	572 231	624 600	1 196 943
1970	91	747 814	669 509	1 417 414
1974	171	817 446[r]	834 926[r]	1 652 543[r]
1975	183	564 962[r]	509 462[r]	1 074 607[r]
1976[p]	83	702 610	764 325	1 467 018

Source: Statistics Canada.
[1] Producers' shipments.
[p] Preliminary; . . Not available; [r] Revised.

Outlook

The world asbestos market is expected to continue in a situation of strong demand and tight supply. For the next several years world demand is projected to increase at approximately 200 000 tonnes of fibre a year, largely on the strength of markets in developing countries. This represents a compounded growth rate of about 4 per cent a year. The relatively slow pace of new projects being developed in Canada indicates that Canada's share of world production will probably diminish in the near-term. For example, the only new property that has advanced to a stage that could result in production within three years is the Abitibi Asbestos project, under evaluation by Brinco Limited and ASARCO Inc.

The short-supply situation will be accentuated by the expected closure in 1978 of Cassiar's Clinton Creek mine which produces about 100 000 tonnes of asbestos fibre a year. This closure will contribute to a possible shortage of asbestos in world export markets of over 400 000 tonnes by 1980. Exports of Russian fibre into Western markets is not expected to increase greatly.

More emphasis will continue to be placed on improved monitoring of the health of workers and on stricter environmental controls inside and outside of plants located throughout most of the industrialized world. This trend will prompt users to seek asbestos substitutes where these are available. Based on present technology, reports suggest that regulations of 2 fibres/cc at the mining-milling stage would drastically reduce the supply of asbestos. Similarly, levels of 0.5 fibres/cc, or lower, associated with manufacturing activity would drastically reduce the demand side of the equation.

If glass fibres can be made alkali-compatible these could replace, or partially replace, asbestos in some asbestos-cement products. No satisfactory cost-competitive substitutes are available for asbestos in many applications, particularly for friction materials.

Prices

Quebec producers raised prices 14 per cent on January 1, 1977. There were no increases in 1976. Cassiar Asbestos Corporation Limited increased fibre export prices 15 per cent in December 1976.

Canadian asbestos prices[1] quoted in Asbestos[2]

	Jan. 1, 1977
	($ per short ton)
Quebec, fob mines	
Crude No. 1	3,300-4,000
Crude No. 2	1,800-2,175
Group	
No. 3 (spinning fibre)	850-1,700
No. 4 (asbestos-cement fibre)	465- 950
No. 5 (paper fibre)	315- 435
No. 6 (waste, stucco, plaster)	230- 275
No. 7 (refuse, shorts)	85- 200
	Dec. 1, 1976
	($ per short ton)
Cassiar, fob North Vancouver, B.C.	
Canadian group	
No. 3 (nonferrous spinning fibre)	
AAA grade	2,093
AA grade	1,664
A grade	1,267
AC grade	913
No. 4 AK grade (single fibre asbestos-cement)	651
No. 4 CP grade	611
No. 4 AS grade	563
No. 4 CT grade	553
No. 5 AX grade	516
No. 5 CY grade	362
No. 5 AY grade	362

[1]As of December 1, 1976 and January 1, 1977. [2]*Asbestos* is a magazine published monthly by Stover Publishing Company.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
31210-1	Asbestos, crude	free	free	25	free
31215-1	Asbestos, yarns, wholly or in part of asbestos, for use in manufacture of clutch facings and brake linings	7½	7½	25	5
31225-1	Asbestos felt, rubber impregnated for use in mcf floor coverings	free	free	25	free
31200-1	Asbestos, in any form other than crude, and all manufactures thereof, nop	15	22½	25	8
31205-1	Asbestos in any form other than crude, and all manufactures thereof, when made from crude asbestos of British Commonwealth origin, nop	free	12½	25	free
31220-1	Asbestos woven fabric, wholly or in part of asbestos for use in manufacture of clutch facings and brake linings	12½	12½	30	8

United States

Item No.		
518.11	Asbestos, not manufactured, crude, fibres, stucco, sand and refuse containing not more than 15 per cent by weight of foreign matter	free

Tariffs (concl'd)

United States

Item No.		On and after Jan. 1, 1970	On and after Jan. 1, 1971	On and after Jan. 1, 1972
		(%)	(%)	(%)
518.21	Asbestos, yarn, slivers, rovings, wick, rope cord, cloth, tape and tubing	5.5	4.5	4
518.51	Asbestos articles not specifically provided for	6	5	4.5
	Articles in part of asbestos and hydraulic cement	(¢ per lb)	(¢ per lb)	(¢ per lb)
518.41	Pipes and tubes and fittings thereof	0.2	0.18	0.15
518.44	Other	0.15	0.1	0.1

Sources: The Custom Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa, Tariff Schedule of the United States, Annotated (1976) TC Publication 749.

Barite and Celestite

G.O. VAGT

Production of barite in 1976 was 100 266 tonnes*, an increase of approximately 23 per cent compared with the 1975 production of 81 356 tonnes. Imports of barium carbonate, one of the most important barium chemicals derived from barite, amounted to 2 410 tonnes valued at $594 000 in 1976.

Barite ($BaSO_4$) is a valuable industrial mineral because of its high specific gravity (4.5), low abrasiveness, chemical stability and lack of magnetic and toxic effects. Its dominant use is as a weighting agent in muds that serve to counteract the high pressures confined by the substrata which are encountered when drilling oil and gas wells.

Barite is found in many countries of the world and is the raw material from which nearly all other barium compounds are derived. Witherite ($BaCO_3$) was formerly of importance but it occurred in relatively large quantities only in the north of England. The United States is the principal producer of barite with about 22 per cent of the total production and is followed by Mexico and West Germany, both with about 6 per cent of the total, according to United States Bureau of Mines (USBM) figures. Canada is eighth in world production and exports 60 per cent of its output, mainly as crude barite, to grinding plants in the United States.

Production and occurrences in Canada

Barite is found in a variety of geological environments: as the principal mineral in veins along with fluorite, calcite and quartz; as a gangue mineral in some lead-zinc-silver deposits; and as irregular replacement deposits in sedimentary rocks. Pure barite is white and is most common in veins; impure barite may be near-white, grey, brown or light red. Barite was produced only from operations in Nova Scotia, Ontario and British Columbia in 1976.

At the Walton, N.S. mine, operated by Dresser Minerals Division of Dresser Industries, Inc., most of the production was obtained from low-grade stockpiles, waste dumps and the tailings pond. Limited quantities of ore are still mined from underground workings although mud and water inflows have not been effectively controlled. Prior to flooding, the barite ore was mined from a large replacement deposit by a block-caving method and hoisted through the same shaft as a lead-zinc sulphide ore mined in conjunction with the barite. Most of the production in 1976 was shipped in crude form to southwestern United States and the remainder was transferred to an affiliated company for use in offshore oil drilling in eastern Canada.

There were two barite producers in British Columbia in 1976. Baroid of Canada, Ltd. recovered barite from tailings at an abandoned lead-zinc mine near Spillimacheen, south of Golden. The tailings were fed as a slurry to separation tables, and the barite concentrate dewatered and shipped by rail for further processing in a grinding plant at Onoway, Alberta. Mountain Minerals Limited mined barite underground from vein deposits near Parson and Brisco in the eastern part of the province, and recovered crude barite from the tailings at the Mineral King mine near Invermere. The crude barite was shipped to the company's plant at Lethbridge, Alberta, for grinding.

Extender Minerals of Canada Limited operated the only barite mine in Ontario after initiating production in 1974. Extender's mine is located near Matachewan, where barite is mined from a vein deposit by open-pit methods with all beneficiation being done on the site.

The higher demand for barite in the United States market accounted for the expansion of exports in 1976. The increase in exports to the United States was accounted for by increased oil well drilling activity, lower import duties on crude barite compared to ground barite, and higher production costs of United States reserves.

There are many occurrences of barite across Canada. Of note are occurrences at Buchans, Newfoundland where there is an estimated 0.5 million tonnes of barite in tailings; in Nova Scotia near Brookfield on the mainland, and east of Lake Ainslie on Cape Breton Island; in northern Ontario, in Yarrow, Penhorwood and Langmuir townships, and on McKellar Island in

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Lake Superior; at mile 397 in northern British Columbia, and north of mile 548 on the Alaska Highway. The Lake Ainslie deposit on Cape Breton Island contains about 2.7 million tonnes of ore grading 44 per cent barite and 17 per cent fluorspar. Feasibility studies to date have not developed an efficient commercial scale separation method for this deposit.

Barite deposits in the MacMillan Pass region of the eastern part of the Yukon Territory continued to be evaluated by several companies. Yukon Barite Company Ltd. expects to produce 20 000 to 30 000 tonnes of barite a year from the TEA property located near the Canol road, about 125 miles northeast of Ross River. The property is under option from Welcome North Mines.

Uses, consumption and trade

The dominant use for barite is as a weighting agent in oil and gas well-drilling muds where its specific gravity assists in counteracting high pressure in oil and gas reservoirs. Principal specifications are usually a minimum specific gravity of 4.25, a particle size of at least 90 per cent minus 325 mesh, and a maximum of 0.1 per cent water-soluble solids.

In 1975 consumption of barite in Canada was an estimated 40 229 tonnes, with about 90 per cent of this utilized in the oil well-drilling industry.

Barite is used in paint as a special filler or "extender pigment". This is a vital constituent that provides bulk, improves consistency of texture, surface characteristics and application properties, and controls prime pigment settling and viscosity of paints. Specifications for barite used in the paint industry call for 95 per cent $BaSO_4$, particle size at least minus 200 mesh, and a high degree of whiteness or light reflectance. Final "wet milled" and "floated" products result in smooth micro crystalline surfaces that prevent agglomeration, thus allowing easy dispersal in water-soluble as well as oil-soluble binders. When barite is used in highly pigmented distemper or latex paints, a degree of light scattering is attributed to the barite, therefore allowing it to function as a pigment.

The glass industry uses barite to increase the workability, act as a flux, assist decolouration and increase the brilliance or lustre of glass. Specifications call for a minimum of 98 per cent $BaSO_4$, not more than 0.15 per cent Fe_2O_3, and a particle size range of 40 to 140 mesh.

The specifications vary for natural barite used as a filler in rubber goods, but the main factors are whiteness and particle size range.

The balance of Canada's barite was used in the manufacture of ceramic products, chemicals, plastics and brake linings. Barite may become an important ingredient in heavy concrete used as a radiation shield.

There is, as yet, no barium chemicals industry in Canada. Some important barium chemicals include the nitrate, acetate, oxide, hydroxide and stearate compounds, all derived from barium carbonate. Two other

Table 1. Canada, barite production, trade and consumption, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Production (mine shipments)	81 356	2 305 819	100 266	1 860 000
Imports				
United States	4 479	485 000	18 097	1 370 000
Total	4 479	485 000	18 097	1 370 000
Exports				
United States	45 606	794 000	60 297	1 168 000
Total	45 606	794 000	60 297	1 168 000
	1974[r]		1975	
Consumption[1]				
Well drilling	51 522[e]		36 044[e]	
Paints and varnish	2 154		2 175	
Glass and glass products[2]	4 179		867	
Rubber goods	120		48	
Other[3]	464		1 095	
Total	58 439		40 229	

Sources: Statistics Canada; provincial Departments of Mines; Department of Energy, Mines and Resources, Ottawa.
[1] Available data reported by consumers, with estimates by Mineral Development Sector. [2] Includes glass fibre and glass wool. [3] Other includes bearings and brake linings, ceramics, chemicals and plastics.
[p] Preliminary; [e] Estimate; [r] Revised.

very important compounds are chemical or precipitated barium sulphate, referred to in the trade as blanc fixe; and lithopone, a chemically precipitated mixture of 70 per cent barium sulphate and 30 per cent zinc sulphide. Lithopone, a white pigment, is still in demand for certain purposes such as undercoatings, filling pastes, emulsion paints and wall paper coatings. In most uses, however, lithopone has largely been replaced by titanium dioxide pigments.

Specifications of barite for the barium chemicals industry call for 95 per cent $BaSO_4$, and not more than 2 per cent Fe_2O_3.

Table 2. Canada, barite production, trade and consumption, 1965, 1970, 1974-76

	Production[1]	Imports	Exports	Consumption[2]
	(tonnes)			
1965	184 181	3 344	167 858	19 700
1970	133 584	6 827	90 305	50 100
1974	78 019	11 678	31 258	58 439
1975	81 356	4 479	45 606	40 229
1976[p]	100 266	18 097	60 297	. .

Sources: Statistics Canada; Department of Energy, Mines and Resources, Ottawa.
[1]Mine shipments. [2]Includes estimates by the Mineral Development Sector.
[p]Preliminary; . . Not available.

World review

There is worldwide production and considerable international trade in barite even though transportation costs in some cases may be greater than the cost of the lump material. World production of barite in 1976 was an estimated 4.7 million tonnes according to the United States Bureau of Mines. An estimated 75 per cent of this quantity was consumed in oil well-drilling operations. Dependence on the oil industry as a principal market means that demand is subject to considerable fluctuation as the tempo of oil and gas exploration varies in time and in geographic location. Conversely, oil and gas exploration takes place throughout the world, resulting in consistent world demand that is most economically served by production from many countries. The viability of any deposit is dominantly influenced by transportation costs to markets.

The United States is by far the world's largest producer of barite. About 30 mines produce an estimated 1 million tonnes derived mostly from Nevada, Arkansas and Missouri, with smaller amounts from other states. Annual imports of barite to the United States for the past several years have been between 550 000 and 700 000 tonnes. Following the United States, which has nearly 22 per cent of the total world production, were Mexico, 6.4; Ireland, 5.8; West Germany, 5.6; Peru, 5.1; Italy, 4.7; France, 2.1; Greece, 2.3; Morocco, 2.9; Canada, 2.1; Yugoslavia, 1.1; other market-economy countries, 18.5 and controlled-economy countries except Yugoslavia, 21.5.

The United States is the principal consumer of barite and used 1.7 million tonnes in 1976. Imports into the United States for the years 1972 to 1975, inclusive, came from Peru, 33 per cent; Ireland, 27 per cent; Mexico, 19 per cent and other, 21 per cent. Of the total 1976 consumption of barite in the U.S. approximately 90 per cent was used in oil-and-gas well drilling. The pattern of consumption of ground barite (excluding the barium chemicals industry) in the United States is similar to that in Canada.

In the United States most major barite producers are carrying out extensive exploration and development programs to assure a continuing supply of barite. Imco Drilling Services completed a new plant with a capacity of 136 000 tonnes a year at Mountain Springs, Nevada, and also carried out expansions at its Battle Mountain, Nevada, grinding plant. Chromalloy plans to produce barite from its Jungle claims near Wells, Nevada. This company also plans to produce barite from the Dameron and Ainsworth properties near Marion, Kentucky.

In Ireland, Milchem, Inc., and Imco Drilling Services continued development work to increase outputs at their respective properties. New output by Milchem will be used by the paint and chemical industry in Britain and new output by Imco will be utilized for drilling in the North Sea. Most barite production from Ireland is utilized either in the United States, the North Sea or in new areas off the coast of Ireland and Wales in the Celtic Sea and the Irish Sea.

In France production commenced from a mine developed by Société des Mines de Garrot. The reported annual capacity of the plant is 18 100 tonnes of gravity concentrate and 108 800 tonnes of flotation concentrate. Most of the production is for the European chemical market.

A new grinding plant was constructed in Holland, under joint venture by the Baroid Division of N L Industries, Inc. and Cementbouw B.V. New plants are also under construction in Algeria, Iran, Mexico, Morocco, and Saudi Arabia. A plant in Mexico, under construction by an Imco affiliate, will have a capacity of 90 700 tonnes a year, and production will be for the drilling market in the United States.

Pakistan Petroleum Ltd. and the provincial government of Baluchistan, Pakistan, commenced production at the Goonga mines near Khuzdar. Production is expected to increase to 70 000 tonnes a year by 1980. Most of the production will be used in the Persian Gulf area.

Outlook

The high level of worldwide oil exploration activity resulting from higher crude oil and natural gas prices during the past three years assures a continuing strong demand for barite for several years. World barite production may be expected to meet requirements

Table 3. World mine production of barite, 1974-76 and reserves, 1976

	Mine production (000 tonnes)			Reserves (000 tonnes)
	1974	1975	1976[e]	
United States	1 003	1 167	1 024	59 000
Mexico	272	300	299	4 000
Ireland	345	295	272	5 000
West Germany	298	248	263	6 000
Peru	227	231	236	4 000
Italy	180	213	218	5 000
Morocco	93	136	136	5 000
Greece	93	107	109	4 000
Canada	78	81	100	3 000
France	105	100	100	3 000
Yugoslavia	50	50	50	3 000
Other free world countries	886	853	862	50 000
Communist countries (except Yugoslavia)	856	922	998	30 000
World totals	4 486	4 703	4 667	181 000

Sources: United States Bureau of Mines, Commodity Data Summaries, January 1977 and United States Bureau of Mines Preprint, 1975. For Canada, Statistics Canada.
[e] Estimated.

because geologic factors suggest that there is good potential for discovery and development of deposits near most regions where there is drilling activity. Also, the major U.S. companies are associated with most of the major producing mines and prospective producers, which allows the companies to adjust to the changing needs of the drilling industry as geographical shifts in activity occur.

Exploration of new barite deposits in Canada and feasibility studies presently under way could bring about changes in the production pattern and the quantity of output in the near future. With continued oil and gas well drilling activity in the Mackenzie Delta, the Arctic regions, and off the east coast of Canada, a growing market for barite in these areas may be expected. The record level of drilling activity in Canada, largely accounted for the development of shallow gas plays in Alberta, suggests that Canadian requirements will be maintained in the province.

In the future, larger quantities of barite may be recovered from mine dumps and tailings ponds in Canada and abroad. Also, an increasingly important source of barite may be as a co-product from the mining of iron, base-metal, fluorspar and rare-earth ores.

The relatively low cost and technical advantages of barite for the drilling-mud market suggests that other materials will not likely be substituted on a large scale in this major application. For example: iron ore is more abrasive and undesirable to handle because of colour, celestite ($SrSO_4$) is more expensive and has a lower specific gravity, and galena (PbS) is too expensive. *Fer-O-Bar*, a semi-synthetic product derived from the calcination of pyritic ores, is now available in commercial quantities and may prove to be a successful substitute for drilling-grade barite in some markets.

Prices

United States prices of barite as reported in Engineering and Mining Journal of December, 1976.

	($ per short ton)
Unground	
Chemical and glass grade:	
Hand picked, 95% $BaSO_4$ not over 1% Fe	42.50 — 50.00
Magnetic or Flotation, 96-98% $BaSO_4$ not over 0.5% Fe	60.00 — 70.00
Imported drilling mud grade, specific gravity 4.20-4.30: cif	
Gulf ports	19.00 — 28.00
Canada	19.00
Ground	
Water, 95% $BaSO_4$ 325 mesh, 50-lb bags	60.00 — 80.00
Dry ground drilling mud grade, 83-93% $BaSO_4$ 3-12% Fe, specific gravity 4.20-4.30	71.00 — 78.00
Imported	
4.20-4.30 specific gravity	31.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
49205-1	Drilling mud and additives	free	free	free	free
68300-1	Barites	free	10	25	free
92842-1	Barium carbonate	10	15	25	10
92818-1	Barium oxide, hydroxide peroxide	10	15	25	10
93207-5	Lithopone	free	12½	25	free

United States

Item No.		
472.02	Barium carbonate, natural, crude	free
472.04	Barium carbonate, natural, ground	6%
		($ per lt)
472.10	Barium sulphate, natural	1.27
472.12	Barium sulphate, natural, ground	3.25
		(¢ per lb)
472.14	Barium sulphate, precipitated (blanc fixe)	0.3
473.72	Lithopone, containing under 30% zinc sulphide	0.43
473.74	Lithopone, containing 30% or more zinc sulphide	0.43+ 3.5%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Tariff Schedules of the United States, Annotated (1976) TC Publication 749.

CELESTITE

Celestite ($SrSO_4$), the main source of strontium, is used to produce commercial strontium compounds, principally strontium carbonate and strontium nitrate. In the sulphate form it is used in the zinc flotation process. Strontium carbonate is used in glass faceplates in colour television sets, where it improves the absorption of X-rays emitted by picture tubes operated at high voltages. An increasing use for this compound is in the manufacture of ferrites, a material required in the production of ceramic permanent magnets, which are used in small electric motors.

Kaiser Celestite Mining Limited, a subsidiary of Kaiser Aluminum & Chemical Canada Investment Limited, closed its celestite mining operation and strontium products plant. Operating problems and cost overruns were associated with the new plant and newly developed process, and markets failed to develop as rapidly as anticipated. Mining of the ore commenced at Loch Lomond, Cape Breton Island, N.S. in 1970 and concentration by flotation began at the mine site in 1971. The concentrate was shipped to the Point Edward, N.S. plant of Kaiser Aluminum & Chemical of Canada Limited for treatment with imported natural sodium carbonate to produce technical and chemical-grade strontium carbonate, commercial-grade strontium nitrate and sodium sulphate. Other firms failed to show sufficient interest in continuing the operation and all equipment will be auctioned in 1977.

In the United States current producers of strontium compounds obtain raw material from Mexico, Spain and the United Kingdom. Similarly, Japanese consumers presently have relatively secure sources of supply.

Prices

United States prices as reported in Chemical Marketing Reporter, December, 1976.

Strontium carbonate	($ per short ton)
glass grade, bags	
carlot, truckload, works	360.00 — 375.00
Strontium nitrate	($ per 100 pounds)
bags, carlot, works	24.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92839-5	Strontium nitrate effective July 1, 1974 to June 30, 1984	free	free	free	free

United States

Item No.		
Strontium Metal		
632.46	Unwrought, waste and scrap	5%
632.68	Alloys of strontium	7.5%
473.19	Strontium chromate pigments	5%
Strontium Compounds		
421.70	Carbonate	free
421.72	Carbonate (precipitated)	6%
421.74	Nitrate	6%
421.76	Oxide	6%
421.82	(mineral celestite)	free
421.84	Sulphate	5%
421.86	Other	5%

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. For United States, Tariff Schedules of the United States, Annotated (1976) TC Publication 749.

Bentonite

G.O. VAGT

Bentonite is a clay composed mainly of the mineral montmorillonite, a member of the smectite group of clay minerals. The term "smectite", as a group name, is growing in acceptance and this usage eliminates confusing terminology that includes "montmorillonite" as both mineral species and group names. Montmorillonite is a hydrated aluminum silicate with weakly-attached cations of sodium and calcium which impart different properties to bentonite, depending on amounts and proportions present. One method of classifying bentonite is based on its swelling capacity when wet. With sodium as the dominant or abundant exchangeable ion, swelling from 15 to 20 times the original dry volume will occur, and when added to water, gel-like masses result. Sodium bentonite also possesses a high dry-bonding strength, especially at high temperatures, a feature important in the manufacture of some ceramic products.

Montmorillonite clays have ion-exchange properties and, by adsorption, absorption and chemical activity, bentonite can collect many types of inorganic and organic compounds, sometimes selectively. In general, the non-swelling or calcium bentonites exhibit the more pronounced adsorptive characteristics. While naturally-occurring clays may exhibit adsorptive or bleaching properties, their efficiencies are commonly improved by acid leaching or, as the process is generally termed, activation.

Another clay, "fuller's earth", also contains mainly smectite-group clay minerals and is very similar to non-swelling bentonite. These clays have natural bleaching and absorbent properties and were originally used by fullers to remove dirt and oil from wool. The terminology is confusing, and bentonite and fuller's earth may, or may not, be separated in world trade and production figures by country.

Bentonites may originate from smectitic clays formed from igneous rocks other than volcanic ash, tuff or glass, or from rocks of sedimentary or uncertain origin. The deposits occur in relatively flat-lying beds of various chemical compositions and impurities; the latter consisting of quartz, chlorite, biotite, feldspar, pyroxenes, zircon and various other minerals. Natural clay may be creamy white, grey, blue, green or brown; and, in places, beds of a distinctly different colour are adjacent. Fresh, moist surfaces are waxy in appearance; on drying, the colour lightens, and the clay has a distinctive cracked or crumbly texture.

Production and occurrences in Canada

Canadian bentonite occurrences are confined to Cretaceous and Tertiary rocks at many localities in Manitoba, Saskatchewan, Alberta and British Columbia. Although clay beds occur in rocks older than Cretaceous, none of these beds in Canada have been identified as bentonite.

Two companies presently mine and process bentonite in Canada, but statistics on total production and exports are not available for publication.

In Alberta, Dresser Minerals Division of Dresser Industries, Inc. recovers swelling bentonite from the Edmonton Formation of Upper Cretaceous age. The deposits are in the Battle River Valley, nine miles south of Rosalind, the site of the company's processing plant. The bentonite is mined selectively in the dry summer months from relatively shallow paddocks or pits. Some natural drying may be done by spreading and harrowing material before trucking it to the plant for drying, pulverizing and bagging. Swelling bentonite from Alberta is used mainly as a drilling-mud additive, a foundry clay, as feed-pelletizing material, as a fire-retardant additive to water and as a sealer for farm reservoirs. Baroid of Canada, Ltd. has discontinued the processing of bentonite at its Onoway plant. This company had mined bentonite from the Edmonton formation at a deposit located 14 miles northwest of Onoway using methods similar to those used by Dresser.

In Manitoba, Pembina Mountain Clays Ltd. mines non-swelling bentonite from the Upper Cretaceous Vermilion River Formation, 19 miles northwest of Morden, which is 80 miles southwest of Winnipeg. Some bentonite is dried and pulverized in a plant at Morden, but the bulk of production is railed from

Morden to the company's activation plant at Winnipeg, where it is leached, washed, filtered, dried, pulverized and bagged. The main use is for decolourizing and purifying mineral and vegetable oils, animal fats and tallows. High sorptive properties also make this bentonite suitable for pet litter and floor-sweeping compounds.

Uses, consumption and trade

Bentonite has many uses, but it generally constitutes only a small part of the final product.

Select swelling bentonite has found widespread and rapidly growing uses as a binder in the pelletizing of iron ore concentrates. About 18 pounds is used in every long ton of concentrate to provide pellets with sufficient "green" strength to withstand handling during the drying and firing stages. The amount of bentonite required varies with the mineralogy and particle size of the concentrate. Approximately 70 per cent of the reported total consumption of bentonite in 1975 was for use in pelletizing iron-ore concentrates. Saskatchewan bentonite has recently been evaluated for iron-ore pelletizing by Inland Cement Industries Limited and shipments have been made to several pelletizing plants. In 1976 Inland sold the rights to its Avonlea, Saskatchewan "bad lands" deposit of sodium bentonite, near Truax, to Avonlea Minerals Industries Ltd.

Special muds used in oil- and gas-well drilling contain about 10 per cent swelling bentonite, which is used principally to prevent the loss of drilling fluid into permeable zones by forming a mud cake on the wall of the drillhole. It also serves as a lubricant and helps to keep the drill cuttings suspended in water-based muds.

Swelling bentonite serves as a binder in moulding sands used by iron and steel foundries. Non-swelling

Table 1. Canada, bentonite imports and consumption, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Imports				
Bentonite				
United States	183 913	3 706 000	274 095	5 288 000
Greece	58 270	1 083 000	—	—
Total	242 183	4 789 000	274 095	5 288 000
Activated clays and earths				
United States	8 467	2 803 000	9 066	2 684 000
Greece	34 778	1 418 000	83 095	2 082 000
France	563	262 000	294	134 000
Other countries	62	28 000	41	20 000
Total	43 870	4 511 000	92 496	4 920 000
Fuller's earth				
United States	1 833	88 000	571	36 000

Consumption[1] (available data)	1973	1974[r]	1975[p]
	(tonnes)	(tonnes)	(tonnes)
Pelletizing iron ore	238 960	199 904	202 401
Well drilling	22 444	25 292	18 967
Foundries	50 569	75 547	59 439
Chemicals	20	39	36
Fertilizer stock and poultry feed	156	757	1 387
Paint and varnish	307	642	290
Other products[2]	1 186	1 518	1 749
Total	313 642	303 699	284 269

Source: Statistics Canada.
[1]Does not include activated clays and earths. Breakdown by Mineral Development Sector, Department of Energy, mines and Resources, Ottawa. [2]Explosives, frits and enamels, refactory brick and cements, ceramic products, petroleum refining and refining vegetable oils, pulp and paper and other miscellaneous minor uses.
[p]Preliminary; [r]Revised; — Nil.

Table 2. Canada, bentonite imports and consumption, 1965, 1970, 1974-76

	Imports[1]		Consumption[2]
	(tonnes)	($)	(tonnes)
1965	174 334	2 310 566	123 610
1970	351 066	5 590 000	262 804
1974	353 770	7 867 000	303 699[r]
1975	287 886	9 388 000	284 269
1976[p]	367 162	10 244 000	. .

Source: Statistics Canada.
[1]Includes bentonite, fuller's earth and activated clays and earths. [2]Includes only fuller's earth and bentonite.
[p]Preliminary; [r]Revised; . . Not available.

bentonite is also used as a binder in some low-temperature foundries.

Swelling bentonite is used as a binder in the pelletizing of base-metal concentrates and stock feeds. It is used in small quantities as a plasticizer in abrasive and ceramic mixes, and as a filler in paints, paper, rubber, pesticides, cosmetics, medicinal products, and cleaning and polishing compounds. Engineering applications are: in grout, for sealing subsurface water-bearing zones, dams and reservoirs; as additives to cements, mortars and concretes to suppress bleeding of the mixing water; as a compacting agent for gravels and soils; and as a ground stabilization medium for excavations when used in a bentonite-water suspension. Bentonite slurry is also effective in fighting forest fires.

Some non-swelling bentonite is used in pelletizing stock feed, as a carrier and diluent for pesticides, and as a cleaning powder for animals.

Activated bentonite is used in decolouring mineral and vegetable oils, animal fats, waxes, beverages and syrups. It is also used in some countries as a catalyst in the refining of fluid hydrocarbons.

Consumption of bentonite in Canada has more than doubled in the last decade, largely because of increased consumption as a binder in iron concentrate pelletizing as more of these plants have been constructed. Consumption of bentonite in well-drilling in the oil and gas industry is subject to considerable fluctuation. Iron and steel foundries require bentonite as a binder for moulding sands, and consumption for this use is continuing to rise. Quantities of activated clays and fuller's earth are imported, mainly from Greece and the United States, and some activitated bentonite from Manitoba is exported to the United States.

Bentonite production in the United States is mainly from extensive deposits in Wyoming, where the name was derived from the Cretaceous Fort Benton Formation. These Cretaceous deposits are the world's outstanding swelling bentonite occurrences and the specifications and standards for bentonite used in industry are based on these high-quality clays. Although there are numerous occurrences of bentonite in many countries it is mined in only a few. Because of the high standards of Wyoming bentonite this material is transported over such long distances that transportation costs commonly exceed the value of the product at the mine, in some cases by several times. However, in recent years Wyoming producers have lost some markets for iron-ore pelletizing in eastern Canada to Greek bentonite producers. The cost spread between rail and ocean transportation is the principal reason for this change. Canada is the main importer from the United States, which also ships some bentonite to Australia and western Europe. In 1976 most United States producers were converting their plants from natural gas to coal-burning equipment for moisture removal.

Non-swelling bentonite, fuller's earth, and bleaching clays are produced in numerous states, the major ones being Florida, Georgia, Mississippi and Texas.

Outlook

The bulk of Canada's bentonite consumption is in pelletizing iron-ore concentrates. Wyoming bentonite remains the most suitable material for this purpose; however, some imports of Wyoming bentonite will be replaced by Saskatchewan bentonite if use of the latter proves to be competitive on a quality and cost basis. The slowdown in import growth since 1970 is a result of a more stable consumption pattern following the completion of new pellet plants. Sidbec-Dosco Limited at Port Cartier, Quebec has a projected 6-million-tonne-a-year iron ore pellet plant to process concentrate from its Fire Lake property. The project should reach maximum output by 1978 and it is anticipated that this plant will result in increased bentonite consumption in the next three years. Countering this expansion, however, some small companies are expected to cease operations before 1980. This will contribute to a slower net growth in bentonite consumption. No changes in production and consumption patterns in industries other than ore pelletizing are forseen.

Prices

United States bentonite prices quoted in Chemical Marketing Reporter, December 27, 1976.

	($)
Bentonite, domestic, 200 mesh, bags, car lots, fob mines, per short ton	15.50-16.00
Bentonite, imported Italian white, high gel, bags, 5-ton lot ex-warehouse, per lb.	.1688

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29500-1	Clays, not further manufactured than ground	free	free	free	free
93803-2	Activated clay	10%	15%	25%	10%
20600-1	Fuller's earth, in bulk	free	free	free	—

United States

Item No.		(¢ per long ton)
521.61	Bentonite	40
521.51	Fuller's earth not beneficiated	25
521.54	Wholly or partly beneficiated	50
		(¢ per lb)
521.87	Clays, artificially activated with acid or other material	0.05 +6% ad valorem

Sources: The Custom Tariff and Amendments, Department of National Revenue, Custom and Excise Division, Ottawa. Tariff Schedules of the United States, Annotated (1976), T.C. Publication 749.
— Nil.

Beryllium

D. PEARSON

Beryllium is a light metal with a specific gravity of 1.85, which falls between those of magnesium and aluminum. Its tensile strength is considerably higher than either one of these metals but in the pure state it is brittle and cannot be rolled or drawn in either the hot or cold condition without special treatment. Beryllium has physical characteristics which make it ideal as a neutron moderator and for X-ray purposes. The oxide of beryllium has excellent strength, thermal conductivity, high electrical resistance at both room and elevated temperatures as well as good resistance to chemical attack and thermal shock.

Occurrences and recovery

The main source of beryllium is beryl, a beryllium-aluminum silicate containing 4 to 4.5 per cent beryllium. Bertrandite, a beryllium silicate, is also used as a beryllium source, especially in the United States. Beryl normally occurs in pegmatite dykes, usually as sparsely disseminated crystals. Rarely does a deposit contain sufficient beryl to make it an economic source, except in Brazil where deposits are mined for gems, and non-gem beryl is a byproduct. Frequently other metals, such as molybdenum and lithium, are recovered as the primary product and beryl as the byproduct. Beryllium may also be found in nonpegmatite deposits such as clay, slate, mica schist, kaolin and in sulphurous spring waters, but none of these are presently considered as likely commercial sources.

The chief sources of beryl as indicated in Table 1 are Brazil, India, the U.S.S.R., Argentina, Uganda, South West Africa and the United States. In 1969 deposits of bertrandite were developed at Spor Mountain and Gold Hill, Utah, by Brush Wellman, Inc. and these are now the main source of beryllium in the United States.

Throughout Canada beryllium-containing deposits have been reported in 75 locations and nearly all are related to granitic intrusions. However, no commercial exploitation occurs at present. Between 1961 and 1972 beryl was recovered as a byproduct from the Molybdenite Corporation of Canada Limited mine at La Corne, Quebec. One or more shipments of beryl were made from the Lyndoch township occurrences near Quadeville, Ontario. An attempt to develop mineable deposits was made in southeastern Manitoba by Dalhart Beryllium Mines & Metals Corporation Limited in 1956 and 1957 without success. A unique deposit of barylite at Seal Lake, Labrador was investigated some years ago and although the mineralization occurs over a very large area results were inclusive.

Several processes have been developed for treating beryllium ore. The two major ones; the fluoride process and the sulphate process, are currently used in the United States to obtain a beryllium oxide concentrate. To obtain metallic beryllium the oxide concentrate is dissolved in an aqueous solution of acid ammonium fluoride. The resulting ammonium-beryllium fluoride is heated to expel the ammonia and the resulting residue of beryllium fluoride is reduced by magnesium in a graphite-lined furnace. Beryllium separates and floats on a molten slag, permitting separation.

Beryllium when cast tends to develop coarse crystals, causing brittleness and low tensile strength. To overcome this problem, powder metallurgy is usually employed to fabricate the metal. Clean vacuum-cast ingots are machined and the resulting chips are ground to a powder in an inert atmosphere. The powder is compacted into a dense fine-grained structure by hot-pressing under vacuum. The compacted ingots can then be extruded, drawn, or rolled to shape.

Production

There is little statistical data available on either world or Canadian consumption of beryllium. Annual world mine production of beryl in 1975 was 3 273 tonnes* and has progressively decreased over the period from 1972 to 1975. Kawecki Berylco Industries, Inc., (KBI) in the United States uses imported beryl to produce beryllium products. Brush Wellman, Inc., another

The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Identified world beryllium resources

	Reserves	Other	Total
	(000 tonnes contained beryllium)		
North America			
United States[1]	25.4	47.2	72.6
Canada	. .	22.7	22.7
Mexico	. .	1.8	1.8
South America			
Argentina	25.4	46.3	71.7
Brazil	139.7	256.7	396.4
Asia			
India	64.4	118.8	183.2
Africa			
Mozambique	5.4	11.8	17.2
Rwanda	10.9	20.0	30.9
Republic of South Africa	15.4	29.0	44.4
Uganda	14.5	26.3	40.8
Zaire	7.3	13.6	20.9
Europe			
U.S.S.R.	60.8	111.6	172.4
Oceania			
Australia	10.9	19.1	30.0
World Total	380.1	724.8	1104.9

Source: U.S. Bureau of Mines, Bulletin 667, *Mineral Facts and Problems*, 1975 Edition.
[1]Includes beryllium content of U.S. domestic bertrandite resources.
. . not available.

American company, produces similar products from its bertrandite mine in Utah. These are the only two producers of beryllium in the United States, and to avoid disclosing company confidential data, their production is not published. Preliminary estimates indicate that world production of beryllium metal in 1976 was 128 tonnes and this was mainly refined in the United States. Canadian imports of beryllium metal and its alloys in 1976 was 16.4 tonnes. Seventy-six per cent of this amount consisted of alloys.

Uses

Beryllium is used in the pure metal form mainly as an alloying element, but the largest application is in the oxide forms. The light weight, high strength and rigidity characteristics of the metal makes it ideal for such aerospace applications as missile components, aircraft brakes, aircraft frames, satellite and space

Table 2. World production of beryl, 1972-75

	1972	1973	1974	1975[p]
	(tonnes)			
USSR[e]	1 361	1 451	1 633	1 597
Brazil	1 550	1 210	1 089	907
Argentina	84	185	186	275
Zambia	187	200	200	200
Australia	62	162	172	. .
Angola	175	115	100	32
Rawanda	103	95	91	18
Other countries	406	177	137	244
World Total	3 928	3 595	3 608	3 273

Sources: US Bureau of Mines, Mineral Industry Surveys 1974, and US Bureau of Mines, Minerals Yearbook Preprint 1976.
[p]Preliminary; [e]Estimated.
. . Not available.

vehicles. The metal is also used in nuclear applications such as fuel container materials, and as a neutron moderator or reflector. However, nuclear applications are limited to those that are not stressed or subject to shock because the metal becomes brittle when exposed to substantial quantities of radiation.

The beryllium industry was founded on the ability of beryllium to harden and strengthen copper. More than half of the beryllium consumed is used in various copper alloys. Beryllium-copper alloys containing 0.5 to 2 per cent beryllium are used in a large variety of applications that require a combination of excellent formability on the soft condition and high hardness in the heat-treated conditions. These alloys have excellent electrical and thermal conductivity. Typical applications include springs, current-carrying springs, contacts for switchgear relays, bellows and brushings. Other applications include non-sparking tools and moulds for the diecasting and plastic industries. Beryllium-nickel alloys have found limited use where a hardenable alloy with high tensile strength at high temperatures is required. Aluminum-beryllium alloys are used to improve the magnesium recovery and casting properties of aluminum-magnesium alloys. Kawecki Berylco Industries reports that *Lockalloy* (beryllium-aluminum) sheet was installed on an experimental aircraft with successful results.

Beryllium oxide is a unique ceramic material that conducts heat well but does not conduct electricity. Its major use is as a heat sink and as an electrical resistor in small electronic devices. Beryllium or its oxide is used to make certain inorganic and organic chemicals. Care must be taken in handling beryllium because of the extremely toxic nature of the dust and fine powder.

Beryl is an important source of gem stones. When pure, beryl is colourless, but impurities impart a variety of colours to the mineral. The deep-green-

Table 3. World mine production of beryllium, 1974-76

	1974	1975	1976[p]
	(tonnes contained beryllium)		
Brazil	44	36	36
Argentina	7	7	6
Zambia	8	8	5
Australia	7	4	4
Other Market Economies	5	4	4
Angola	4	—	—
Southern Rhodesia	—	3	3
Rawanda	4	2	1
Uganda	—	2	1
Central Economy Countries	65	65	68
World total	144	131	128

Source: U.S. Bureau of Mines Commodity Data Summaries, 1977.
[p] Preliminary.

coloured emerald has long ranked among the most costly of jewels. Aquamarine, a sea-blue variety, is more plentiful than emeralds and generally is of far larger size. A rose-pink variety is called Morganite, and Heliodor is golden-yellow. Most of the world's emeralds have come from Colombia, South America. Other sources are the Ural Mountains of Russia, Brazil, and the United States. The larger aquamarines originate in Brazil, the most abundant source being Minas Gerais. Splendid stones have been found in Madagascar in the Ural Mountains in Russia and several localities in the United States.

Canada, beryllium imports 1976

	(tonnes)	($)
Beryllium Metal	3.9	58,000
Beryllium Alloys	12.5	161,000

Source: Statistics Canada.

Outlook

Because of the relatively high price of beryllium it is expected that it will be used mainly in applications as outlined above. Use of beryllium-copper alloys will continue to increase slowly as the economy improves. New alloy developments may increase beryllium's use where light weight with strength is essential. Continued, but modest, growth in the use of beryllium oxide in the electronics industry is expected.

Specifications and prices

The price of beryllium ore, described as 10-12 per cent Beryllium Oxide, in 1976 ranged between $U.S. 44.09 and $U.S. 46.29 per tonne for most of the year. Vacuum cast beryllium ingots of 97 per cent purity are quoted at $U.S. 240 per kilogram. Three standard alloys are marketed. These, with their prices, are described as follows:

	Price Range 1976
	$US/kg
U.S. Beryllium Copper Alloy No. 25- 2% Be content Available in strip, rod, bar and wire	8.66-9.26
U.S. Beryllium-Copper Casting Alloy No. 20C, 2- 2¼% Be 5-lb. ingots	5.58-6.15
U.S. Beryllium-Copper Master Alloy — 4% Be, 5-lb. ingots	Dec. 23, 1974 1.30.07 1976 No change

Beryllium rod price delivered, 5-in. diameter, has remained steady since February 1975 at $U.S. 340.68 to $U.S. 340.81 per kilogram.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
34907-1	Beryllium-Copper alloys	5	5	25	3
35101-1	Metals nop not including alloys in lumps, powders, ingots or blocks.	free	5	25	free

United States

Item No.		On and after January 1, 1976	Statutory
		(%)	(%)
601.09	Ores and concentrate	free	free
628.05	Unwrought waste and scrap	8.5 ad. val.	25 ad. val.
628.10	Beryllium wrought	9 ad. val.	45 ad. val.
628.12	Beryllium-copper master alloy	0.6¢/lb+ 10% ad. val.	3.0¢/lb+ 25% ad. val.
417.90	Beryllium compound, oxide or carbonate	5 ad. val.	25 ad. val.
417.92	Other	5 ad. val.	25 ad. val.

Bismuth

G.R. PEELING

Bismuth is obtained in Canada in the processing of some lead-zinc, lead-zinc-copper and copper ores. The more important sources are the lead-zinc-copper ores mined in New Brunswick and the lead-zinc ores mined in southeastern British Columbia. Smaller amounts are recovered from ores mined in Ontario and Quebec. Bismuth is also recovered from the flue dusts at the copper smelter of Gaspé Copper Mines, Limited in Quebec. The dusts are then shipped to Brunswick Mining and Smelting Corporation Limited in New Brunswick for refining.

Bismuth production in Canada in 1976, based on bismuth recovered from domestic ores and concentrates plus the bismuth content of bullion and concentrates exported, was 196 900 kilograms valued at $3 130 000. This represents a 25.7 per cent increase in production from the level of 156 605 kilograms in 1975. Inventory of metallic bismuth held by consumers as of December 31, 1975 totalled 4 162 kilograms and is estimated to have increased by about 10 per cent during 1976.

In 1976 world production of bismuth as estimated by the United States Bureau of Mines (USBM), excluding United States production, was about 3.67 million kilograms, a decrease of less than 1 per cent from the 3.70 million kilograms produced in 1975. Bolivia and Japan were the two leading producers, followed by Peru, Mexico and Australia. The United States, which is a substantial producer from its own and imported ores, does not publish production statistics because one company, ASARCO Incorporated, accounts for almost all of the country's refined metal output. Nonetheless, apparent production in the period 1965 to 1975 averaged 485 000 kilograms and at this level, the United States ranks among the top 6 world producers.

Domestic sources

The Smelting Division of Brunswick Mining and Smelting Corporation Limited (BM&S) produces bismuth metal and alloys at its plant at Belledune, about 40 kilometres northwest of Bathurst, New Brunswick. Production of bismuth in 1976 was in the form of an 8 per cent bismuth-lead alloy and a 50 per cent bismuth-lead alloy containing 132 450 kilograms of bismuth. This was down slightly from the 1975 production level of 156 500 kilograms, part of which was stockpiled. The BM&S production is derived mainly from its own ores from the No. 6 and No. 12 mines and to a smaller extent from flue dusts rich in bismuth and lead obtained from Gaspé Copper Mines, Limited in Quebec. The Kroll-Betterton process is used to treat the desilverized lead bullion and produce a bismuth-lead-calcium-magnesium dross. The dross is then refined pyrometallurgically with chlorine to produce bismuth metal or alloy.

The other primary bismuth metal producer is Cominco Ltd. at its lead-zinc plant in Trail, British Columbia. Cominco derives most of its output from lead concentrates produced at its Sullivan lead-zinc mine at Kimberley. Other sources included lead concentrates from other company mines and custom shippers, both domestic and foreign. Lead bullion produced from the smelting of these concentrates contains about 0.05 per cent bismuth. Bismuth is recovered as 99.99+ per cent metal from the treatment of residues resulting from the electrolytic refining of the lead bullion. Bismuth for use in research and the electronics industry is further processed at the company's nearby high-purity plant to give it a purity of up to 99.9999 per cent. Production in 1976 totalled 118 723 kilograms compared with 99 791 kilograms in 1975. (Part of this production is derived from imported materials.)

During 1976 the Sullivan Mining Group Ltd. continued to study the economic feasibility of developing its Mount Pleasant tungsten-bismuth-molybdenum property about 64 kilometres north of St. Andrews in Charlotte County, New Brunswick. The Sullivan Mining Group has an 89 per cent interest in the property through its ownership of Brunswick Tin Mines Limited. The other 11 per cent of Brunswick Tin is owned by Mount Pleasant Mines Limited. Ore reserves in the North Zone are estimated at 11.4 million tonnes*

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

and in the Fire Tower Zone at 27.2 million tonnes. Together, the two zones grade 0.2 per cent tungsten, 0.08 per cent bismuth and 0.08 per cent molybdenum. Negotiations are in progress with potential associates in the development of the property, which is expected to cost about $30 million. The major hindrance to development in the past has been the complex metallurgy of the orebody but with the successful completion of metallurgical testing of the ores in late 1975 at the Department of Energy, Mines and Resources in Ottawa, the company is confident that the property can be brought to the production stage in the near future. Bismuth production at the proposed milling rate of 1 350 tonnes a day could be in the range of 250 000 to 300 000 kilograms a year.

Improvements in mill procedures and equipment in 1976 at the Silver Bear mine of Terra Mining and Exploration Limited resulted in an increase in milling capacity to 180 tonnes a day and in improved recovery of bismuth — up to 80 per cent. In previous years a substantial amount of bismuth was lost in the tailings, resulting in concentrate settlements being penalized because of the low grade. As a result of this improvement in recoveries and because of increasing transportation costs from the Camsell River minesite near Great Bear Lake, Northwest Territories, the company is considering the installation of a refinery furnace to treat separate silver and bismuth concentrates. Terra is also involved in a joint venture with Norex Resources Ltd. on the latter's Camsell River silver-bismuth property, 11 kilometres southeast of the Silver Bear mine. As of the first quarter of 1977, Terra had completed an all-weather road to the property and driven a 520-metre decline to the ore zone. Initial assay results have been disappointing for silver, but bismuth grades have varied from 0.04 to 6.5 per cent. If the property is brought into production all ore will be treated at the Silver Bear mill.

World developments

With the exception of the United States, the world bismuth industry suffered through another unspectacular year. The economic recession which affected all industrialized countries during 1975 and 1976 resulted in lower world production of bismuth as well as lower demand. In addition, large inventories carried over from 1974 have kept metal availability surplus to demand throughout 1975 and 1976.

United States. Consumption of bismuth increased 71 per cent in 1976, while imports increased 75 per cent and exports declined 47 per cent. Consumer stocks increased 7 per cent from 204 662 kilograms at year-end 1975 to 219 454 kilograms at year-end 1976. All major segments of bismuth use showed impressive gains from the recession levels of 1975. The use of bismuth in the manufacture of industrial and laboratory chemicals and pharmaceuticals increased 152 per cent. Most of this increase is attributed to increased production of acrylonitrile where bismuth is used as a catalyst. Bismuth metal consumed in the manufacture of fusible alloys increased 29 per cent, while bismuth used for metallurgical additives increased 10 per cent. The last two end-use categories

Table 1. Canada, bismuth production and consumption, 1975-76

	1975		1976^p	
	(kilograms)	($)	(kilograms)	($)
Production, all forms[1]				
New Brunswick	134 098	2 326 640	139 000	2 210 000
British Columbia	19 164	261 931	24 350	387 000
Quebec	904	15 700	1 750	28 000
Ontario	2 439	42 325	13 800	219 000
Northwest Territories	—	—	18 000	286 000
Total	156 605	2 646 596	196 900	3 130 000
	1974		1975	
	(kilograms)		(kilograms)	
Consumption, refined metal (available data)				
Fusible alloys	2 194		2 314	
Other uses	27 084		26 953	
Total	29 278		29 267	

Sources: Statistics Canada and Mineral Development Sector, Department of Energy, Mines and Resources.
[1]Refined bismuth metal from Canadian ores, plus recoverable bismuth content of bullion and concentrates exported.
^{p}Preliminary; — Nil.

Table 2. Canada, bismuth production and consumption, 1965, 1970, 1974-76

	Production all forms[1]	Consumption[2]
	(kilograms)	
1965	194 482	21 909
1970	267 774	11 135
1974	111 006	29 278
1975	156 605	29 267
1976[p]	196 900	. .

Source: Statistics Canada.
[1]Refined bismuth metal from Canadian ores, plus recoverable bismuth content of bullion and concentrates exported. [2]Refined bismuth metal reported by consumers.
[p]Preliminary; . . Not available.

are still well below the 1973 levels of consumption whereas the chemical and pharmaceuticals sector achieved a new high for the 1970s.

The low level of exports from the United States is an indication of the sluggishness of the European market where consumers were well stocked and demand was stagnant.

Canadian exports to the United States market, as shown by U.S. statistics, almost doubled in 1976 to a level of 45 805 kilograms when compared with 23 198 kilograms in 1975. As a percentage of total U.S. imports, Canada supplied 3.8 per cent in 1975 and 4.3 per cent in 1976.

The General Services Administration (GSA) did not sell any bismuth from the government stockpile in 1975, leaving 952 545 kilograms at year-end. A new stockpile objective of 349 720 kilograms was established by the Federal Preparedness Agency in October 1976, leaving 602 825 kilograms as excess. The whole question of the policy of a national stockpile was reopened when President Carter took office. Stockpile inventories remain frozen until the review is completed and a new policy established.

Australia. The major bismuth producer, Peko-Wallsend Ltd., continued to adjust production to the adverse market conditions prevailing for copper in 1976. The company operated three ore sources in 1976 — the Peko, Warego and Juno mines — after closing the Orlando mine and putting it on a care and maintenance basis in 1975. Bismuth production, in concentrates, was exported mainly to Japan. The Gecko mine is under development and being readied for copper production. Ore reserves for the three mines as of mid-1976 were given as 7.4 million tonnes grading 2.6 per cent copper, 0.25 per cent bismuth and 5 grams of gold a tonne on a weighted average basis. Included in this total is the Juno mine which has ore reserves of 10 000 tonnes and is expected to close late in 1976 or early 1977. The company's Tennant Creek copper smelter and bismuth plant remains closed and major technical changes are planned prior to its reopening. The plant was closed in early 1975 due to poor copper markets and technical production difficulties. Test work at the company's Mount Morgan copper smelter has confirmed that when Tennant Creek is reopened, bismuth will have to be separated from the copper concentrates by flotation methods and then treated in Pierce-Smith converters instead of the existing Kaldo rotary units.

Table 3. World production of bismuth, 1974-76

	1974	1975	1976[e]
		(kilograms)	
Peru	666 300	680 400[e]	589 700
Bolivia	620 500	676 300	680 400
Japan	833 200	671 300	680 400
Mexico	718 000	445 000	449 000
Australia	1 169 400	421 800[e]	417 300
People's Republic of China	249 500[e]	249 500[e]	. .
Canada	111 000	156 600	196 900
Republic of Korea	131 100	112 900	113 400
Romania	81 700[e]	81 600[e]	. .
U.S.S.R.	59 000[e]	59 000[e]	. .
France	57 200	59 000[e]	. .
Other countries	128 800	84 400	539 800
Total[1]	4 825 700	3 697 800	3 666 900

Sources: Statistics Canada and Department of Energy, Mines and Resources for Canada; for remaining countries, U.S. Bureau of Mines, *Minerals Yearbook* Preprint 1975 and U.S. Commodity Data Summaries, January 1977.
[1]Total for listed figures only; it excludes United States production, which is not available for publication, as well as that of some other smaller producing countries.
[e]Estimated; . . Not available.

Peko-Wallsend expects the smelter changes for Tennant Creek to require about 18 months for completion. Consequently it will be late 1978 or early 1979 before the plant is back in production at its annual rated capacity of 1 200 tonnes of crude bismuth bullion, provided copper markets are sufficiently improved.

Pacific Copper Ltd., 48 per cent owned by Pacific Copper Mines Ltd. of Canada, has obtained a 60 per cent option on a 22.8 million-tonne tungsten-bismuth property near Glen Innes, New South Wales. Previous work has indicated a grade of 0.35 per cent ferberite ($FeWO_4$) and 0.03 per cent bismuth for the ore. A letter of intent has been signed with a potential buyer for output from the property and the company planned to announce a possible start-up date for late 1976 or early 1977.

Bolivia. Traditionally a major supplier of bismuth, production increased marginally to 680 400 kilograms in 1976, as estimated by the USBM, from 676 300 kilograms in 1975. The state-owned Corporacion Minera de Bolivia (Comibol) operates the new 650-tonne-a-year bismuth refinery at Telemayu. Prior to the refinery's start-up in late 1975, crude bismuth bullion from the smelter was exported for refining in Europe. The depressed market for metal in 1975 and early in 1976 forced the government to announce that refinery output would be restricted to 400 tonnes in 1976. From the estimate of production by the USBM it seems likely that crude bullion from the smelter continued to be shipped to Europe for processing.

Uses

A major use of bismuth is in pharmaceuticals, cosmetics and industrial and laboratory chemicals, including catalytic compounds. Various bismuth compounds, salts and mixtures are used in pharmaceuticals for indigestion remedies, antacids, burn and wound dressings. The consumption of bismuth indigestion remedies is on the decline since France made such compounds a prescription drug item. France is the leading consumer in this category. Insoluble salts of bismuth are given to patients before X-ray examination of the digestive tract. Cosmetics containing bismuth oxychloride, which imparts a "pearlescent" glow to eye shadow, lipstick, nail polish and powders, comprise one of the larger end-use markets of bismuth, but consumption in this market depends on changing fashion trends and is declining.

Another important outlet for the metal is fusible or low-melting-point alloys for fire-protection devices, electrical fuses, fusible plugs and solders. Many of these alloys contain 50 per cent or more bismuth, with the chief additive metals being cadmium, lead and tin. In safety applications, the dependability of the melting temperatures of the various bismuth alloy compositions is of utmost importance. Pure bismuth metal expands 3.3 per cent on changing from a molten to a solid state. Nonshrinking, low-melting-point bismuth alloys are used in the holding of jet engine airfoil blades during the machining of the root sections. Bismuth-tin alloys are sprayed on patterns to make moulds in the plastic industry.

Table 4. United States consumption of bismuth by principal uses

	1975	1976
	(kilograms)	
Fusible alloys	182 313	235 255
Other alloys	11 797	9 191
Pharmaceuticals[1]	250 979	631 248
Experimental uses	323	3 972
Metallurgical additives	188 785	206 811
Other uses	3 563	6 946
Total	637 760	1 093 423

Source: U.S. Bureau of Mines Mineral Industry Surveys.
[1]Includes industrial and laboratory chemicals.

The metal is also used as an important additive to improve the machinability of aluminum alloys, malleable irons and steel alloys and, with indium, forms a low-melting alloy used in the ophthalmic industry for holding lenses. The United States Atomic Energy Commission uses bismuth in many nuclear research applications because of the metal's low thermal neutron absorption rate.

Bismuth is used in catalysts in the production of acrylonitrile for acrylic fibres and plastics. This use suffered some decline in the 1960s but technological improvements in the process have led to increased demand in the 1970s. The rubber industry also uses a bismuth compound to accelerate the vulcanization process.

Outlook

The major western world economies are recovering only very slowly from the recession of 1975 and the outlook for 1977 is one of continued modest growth. Although there is not likely to be an overly strong demand turnaround in the bismuth industry some price and demand improvement is foreseen for the second half of the year.

Bismuth is mainly a byproduct of the copper and lead industry. The depressed market conditions for copper since late 1974 has kept and will keep bismuth output from this source restricted, probably through 1977 and possibly well into 1978. Although lead enjoyed markedly improved demand in 1976, its coproduct relationship with zinc and that metal's poor market performance kept lead mine output down. Consequently the supply of bismuth has been restricted and is likely to remain at historically low levels until there is a general nonferrous metals recovery of some consequence.

Bismuth demand, in particular, depends on the recovery of the aircraft, automobile, chemical and pharmaceutical industries. Such a recovery appears to be progressing only very slowly outside the United States.

In the 1978 to 1980 period, if demand for all base metals improves, there will be a concomitant increase in bismuth output, particularly in Australia, Peru, Canada and the United States.

The USBM has revised downward its forecast of annual growth in bismuth demand in the period to 1980 from 1.4 per cent to 0.8 per cent. The projected growth in demand in the period 1980 to 2000 remains at 0.7 per cent. Both forecasts use 1973 as a base.

Prices

The Canadian and United States domestic producer price of bismuth reflected the uneventful nature of the market in 1976 as they remained unchanged at $7.50 a pound in their respective currencies.

Dealer quotes on the New York market opened the year at $5.50 to $5.60 a pound, peaked in March at $6.00 to $6.85 a pound, then declined during the rest of the year as there was very little spot demand for the metal. The dealer price touched a low of $4.50 in mid-December and closed out the year in the range of $4.65 to $4.80 a pound.

The price outlook for 1977 remains uncertain. Consumers, despite the better year in 1976, still have large inventories to work off in the United States. Demand in Europe is still lagging. It appears that there is sufficient slack in the system to accommodate a moderate increase in demand before there will be upward pressure on producer prices in North America. The forecast is for prices to remain weak in the first half of 1977, with the possibility of a price increase late in the year as economies continue to recover from the recession level of 1975.

Canadian bismuth price as quoted by Cominco Ltd. in 1976:

Bismuth metal, 99.994+% pure, per pound	
January 1 — December 31	$7.50

United States bismuth price as quoted in Metals Week in 1976:

Bismuth metal, 99.99% pure, major producer price, per pound, short ton lots	
January 1 — December 31	$7.50

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
33100-1	Bismuth ores and concentrates	free	free	free	free
35106-1	Bismuth metal, not including alloys, in lumps, powders, ingots or blocks	free	free	25%	free

United States

601.66	Bismuth ores and concentrates	free
632.10	Bismuth metal, unwrought; waste and scrap	free
632.64	Alloys of bismuth, containing by weight not less than 30% lead	free
632.66	Other alloys of bismuth	9%
633.00	Bismuth metal, wrought	9%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States Annotated (1976) TC Publication 749.

Cadmium

D.H. BROWN

Although cadmium is a relatively rare element in the earth's crust, it occurs most commonly as the sulphide, greenockite (CdS) which is found associated with zinc sulphide ores, particularly sphalerite [(Zn, Fe)S]. The presence of cadmium during sphalerite formation results in the formation of greenockite crystals on the surface and between the sphalerite crystals. To a very small degree cadmium also displaces zinc within the sphalerite crystal structure. The intimate association of cadmium with zinc minerals continues even during separation of multi-mineral ores into concentrates, such that small amounts of zinc reporting to lead and copper concentrates will be accompanied by a proportionate amount of cadmium. There are no known commercial reserves of cadmium and, accordingly, reserves at any time are a function of zinc reserves, and specifically the cadmium content of those reserves. Cadmium recoveries are generally estimated to be 70 to 90 per cent from ore to concentrate and 45 to 75 per cent from concentrate to metal, or 31.5 to 67.5 per cent overall.

Cadmium metal is recovered as a byproduct of zinc smelting and refining and, since secondary sources are considered negligible in terms of total supply, cadmium production or supply is therefore strictly a function of zinc metal production, which bears little or no relationship to the demand for cadmium. Because cadmium represents only 2 to 3 per cent of zinc plant revenues, its supply is virtually inelastic to price fluctuations.

Generally, cadmium is recovered in fumes collected during the roasting of zinc-bearing ores and concentrates, or in precipitates obtained during the purification of zinc sulphate solution resulting from the sulphuric acid leaching of calcine, which is the product of roasting. In Canadian zinc plants, which are all electrolytic, cadmium metal is next recovered either by the electrolytic process whereby the cadmium-bearing precipitate is redissolved in sulphuric acid and plated out in electrolytic cells, or by a purification process in which cadmium-bearing precipitates are releached in sulphuric acid, then filtrated and purified. The purified solution is then cemented with zinc dust to produce cadmium sponge which, in turn, is filtered, briquetted, melted and cast. At primary zinc distillation plants cadmium is reduced and vaporized with zinc in a retort or furnace. The vapour is condensed and cadmium (BP*776°C) is separated from zinc (BP 905°C) by fractional distillation.

Production of cadmium metal in the western world during 1976 is estimated to be 12 504 tonnes** compared with 11 720 tonnes in 1975. Consumption is also estimated to have increased to 13 738 tonnes in 1976 from 9 102 tonnes in 1975. The apparent strong recovery from 1975 is also indicated by the rise in world prices for cadmium which increased 50 per cent during 1976 from $2.00 per pound to $3.00 per pound.

The General Services Administration in the United States sold 67 tonnes of cadmium metal from the strategic stockpile in 1976; however, on October 1, 1976 a revised stockpile goal of 11 204 tonnes was established by the Federal Preparedness Agency which left the stockpile in a deficit position of 8 333 tonnes and precluded further disposals.

In Canada metal production increased to 1 342 tonnes in 1976 from 1 142 tonnes in 1975. Domestic shipments increased from 105 tonnes in 1975 to 123 tonnes in 1976 and export shipments increased very markedly to 1 556 tonnes in 1976 from 638 tonnes in the depressed year prior. The United States and the United Kingdom remained Canada's major markets, accounting for 92 per cent of total exports, with the balance being shipped to The Netherlands, Belgium, and South Africa. Canada remained the third-largest producer of cadmium metal in the western world in 1976, following Japan at 2 502 tonnes and the United States at 1 663 tonnes.

A survey of cadmium consumers in Canada as shown in Table 3 by Statistics Canada indicates that usage in cadmium plating applications is declining,

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*Boiling point.

**The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

although overall usage is increasing due to growth in chemicals, pigments and alloys other than solder. Total end-usage accounted by this survey amounted to 53.8 tonnes in 1976 compared with 38.2 tonnes in 1975. Unfortunately, the tonnage represented in this survey does not reconcile closely with domestic shipments of metal by producers, which amounted to 123.4 tonnes in 1976 and 104.9 tonnes in 1975. Accordingly, the survey cannot be considered to be a true estimate of total consumption in Canada. Other sources, such as the World Bureau of Metal Statistics in London, England, report Canadian consumption of cadmium in 1976 to be 260 tonnes; however, this level also appears to be unreliable.

Canadian production

Canadian mine production in 1976 as reported by Statistics Canada was 1 292 tonnes compared with 1 192 tonnes in 1975. These figures represent the metallic cadmium recovered at domestic zinc refineries from Canadian ores, plus the recoverable content of ores and concentrates exported. The Canadian mines listed in Table 4 produced approximately 3 391 tonnes of cadmium in zinc concentrates in 1976, compared with 3 492 tonnes in 1975. The difference between data reported by Statistics Canada and that shown in Table 4 stems from the fact that many mining companies are not paid for their cadmium in zinc concentrate and thus did not report its content in their shipments of concentrate. For the same reason, most mines do not assay for cadmium on a regular basis, and accordingly many of the productions listed in Table 4 are estimated composite assays of annual production.

Metallic cadmium is recovered as a byproduct at the electrolytic zinc plants of Cominco Ltd. at Trail, British Columbia; Hudson Bay Mining and Smelting Co., Limited at Flin Flon, Manitoba; Canadian Electrolytic Zinc Limited at Valleyfield, Quebec; and Texasgulf Canada Ltd. near Timmins, Ontario. Cadmium metal production by these companies in 1976 increased to 1 342 tonnes, equivalent to 2.84 kilograms cadmium per tonne of zinc metal produced, compared with 1 142 tonnes in 1975 equivalent to 2.68 kilograms cadmium per tonne of zinc metal produced.

Table 1. Canada, primary cadmium statistics, 1974-76

	1974	1975	1976
		(tonnes)	
Mine production[1]	3 765	3 492	3 391
Metal production	1 153	1 142	1 342
Metal production capacity	1 705	1 705	1 705
Export metal shipments	901	638	1 556
Domestic metal shipments	104	105	123

Sources: Statistics Canada; Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Cadmium content of zinc concentrate production as per Table 4.

Newfoundland. The Buchans unit of ASARCO Incorporated and Newfoundland Zinc Mines Limited are the only cadmium producers in the province. Together they produced 168 tonnes of cadmium in zinc concentrate. Cadmium production for Newfoundland Zinc Mines Limited is expected to double next year owing to higher concentrations of cadmium in underground ores.

Table 2. Canada, cadmium metal capacity, 1976

Company and Location	Annual Capacity
	(tonnes)
Canadian Electrolytic Zinc Limited, Valleyfield, Quebec	544
Cominco Ltd., Trail, British Columbia	544
Hudson Bay Mining and Smelting Co., Ltd., Flin Flon, Manitoba	163
Texasgulf Canada Ltd., Timmins, Ontario	454
Total Canada	1 705

Source: Operators List 3. *Metallurgical Works in Canada, Nonferrous and Precious Metals,* January 1976, Department of Energy, Mines and Resources, Ottawa.

New Brunswick. Of the three producers in the province only Nigadoo River Mines Limited has a sufficient grade of cadmium in zinc concentrate to be payable, and at 0.65 per cent is the second-highest grade in Canada. Production from this mine in 1976 was 58 tonnes of cadmium in zinc concentrate compared to a provincial total of 309 tonnes; however, it is scheduled to close in 1977.

Quebec. Canadian Electrolytic Zinc Limited produced 172 tonnes of refined cadmium in 1976 compared with 182 tonnes in 1975. Concentrates treated include those produced by Mattagami Lake Mines Limited, Orchan Mines Limited, Mattabi Mines Limited, the Geco Division of Noranda Mines Limited and Newfoundland Zinc Mines Limited. Except for Geco with its 0.37 per cent grade of cadmium in zinc concentrate, the other mines reported much lower cadmium contents, which account for the relatively low yield of 1.51 kilograms cadmium metal per tonne of zinc metal produced.

Lemoine Mines Limited commenced production at the start of the year and produced 37 tonnes of cadmium in zinc concentrate during the year. The average grade of cadmium in zinc concentrate was 0.28 per cent. Production of cadmium in the province by the principal mines totalled 303 tonnes in 1976.

Ontario. Texasgulf Canada Ltd. produced 1 070 tonnes of cadmium in zinc concentrate at its Kidd Creek mine during 1976, making it the largest cadmium-producing mine in Canada. The company's refinery at Timmins processes about one-half of this production, with the balance exported. Zinc concentrates produced at Kidd Creek assay 0.25 per cent cadmium and, along with those produced by the South Bay Division of Selco Mining Corporation Limited and the Geco Division of Noranda Mines Limited which assay 0.23 per cent and 0.37 per cent respectively, these concentrates contain the majority of the payable cadmium contents produced in the province. In 1976 Ontario's production of cadmium in zinc concentrate totalled 1 620 tonnes, the largest in Canada.

Manitoba and Saskatchewan. Cadmium mine production in these provinces is limited to Hudson Bay Mining & Smelting Co., Limited and Sherritt Gordon Mines Limited, both of which report a low grade of

Table 3. Cadmium production, exports and consumption, 1975-76

	1975		1976p	
	(kilograms)	($)	(kilograms)	($)
Production				
All forms[1]				
Ontario	666 025	5 011 427	690 000	3 992 000
British Columbia	320 926	2 414 769	413 000	2 390 000
Quebec	123 912	932 360	109 000	629 000
Manitoba	43 910	330 399	34 000	192 000
New Brunswick	24 199	182 084	24 000	139 000
Saskatchewan	5 592	42 075	14 000	82 000
Newfoundland	4 923	37 041	5 000	26 000
Yukon	2 050	15 423	3 000	12 000
Northwest Territories	137	1 027	—	—
Total	1 191 674	8 966 605	1 292 000	7 462 000
Refined[2]	1 142 502		1 342 269	
Exports				
Cadmium metal				
United States	286 514	1 856 000	1 057 305	5 823 000
United Kingdom	246 424	1 584 000	382 190	2 089 000
Netherlands	20 130	90 000	84 712	366 000
Belgium and Luxembourg	44 672	243 000	30 005	177 000
South Africa	—	—	1 000	5 000
Other countries	40 057	166 000	560	7 000
Total	637 797	3 939 000	1 555 772	8 467 000

	1974	1975	1976
		(kilograms)	
Consumption			
Cadmium metal[3]			
Plating	34 399	27 624	26 142
Solders	1 098	2 505	3 398
Other uses[4]	12 379	8 080	24 275
Total	47 876	38 209	53 815

Source: Statistics Canada.
[1]Production of refined cadmium from domestic ores, plus recoverable cadmium content of ores and concentrates exported. [2]Refined metal from all sources and cadmium sponge. [3]Available data reported by consumers. [4]Mainly chemicals, pigments and alloys other than solder.
p Preliminary; — Nil.

cadmium in zinc concentrate. The electrolytic zinc plant of Hudson Bay at Flin Flon treats concentrates produced in the two provinces and some shipped from the Northwest Territories. Production at the plant was 128 tonnes of cadmium metal in 1976, equivalent to 2.34 kilograms per tonne of zinc metal produced. Total mine production within the two provinces by the two mine producers amounted to 208 tonnes of cadmium in zinc concentrate.

British Columbia. Metallic cadmium is recovered at the Trail Electrolytic Zinc plant of Cominco Ltd. from zinc concentrates produced at the Sullivan and H.B. mines, as well as concentrates from the Pine Point mine in the Northwest Territories. The other significant production in the province comes from Western Mines Limited which produced 73 tonnes of cadmium in zinc concentrates having a grade of 0.23 per cent cadmium. Total production of cadmium in zinc concentrate for the province was 378 tonnes during 1976.

Yukon Territory. United Keno Hill Mines Limited and Cyprus Anvil Mining Corporation were the only mine producers of cadmium in zinc concentrate, producing 83 tonnes in 1976. Although production is small, United Keno has the highest cadmium grade in zinc concentrate in Canada at 0.67 per cent cadmium. Cyprus Anvil's cadmium production is contained in both a zinc and bulk concentrate, but concentrations are very low.

Northwest Territories. Pine Point Mines Limited and Nanisivik Mines Ltd. were the only producers of cadmium in zinc concentrate during 1976, with a production of 322 tonnes. Nanisivik Mines Ltd. commenced production of zinc concentrates on September 30, 1976 and should produce about 292 tonnes of cadmium in zinc concentrate annually compared to the 27 tonnes recorded in 1976.

Uses

Cadmium is a soft, ductile, silvery-white electropositive metal with a valence of two. It is used mainly for electroplating other metals or alloys; principally iron and, to a lesser extent, copper, to protect them against oxidation. A cadmium coating, like a zinc coating, protects those metals lower in the electromotive series by physical enclosure and by sacrificial corrosion. Cadmium is usually preferred to zinc as a coating because it is more ductile, is slightly more resistant to common atmospheric corrosion, can be applied more uniformly in recesses of intricately shaped parts, and can be electro-deposited with less electric current per unit of area covered. It is also preferred for its more aesthetic appearance. However, because it is more costly and much less plentiful than zinc, it is not as widely used. Improvement in zinc electroplating techniques in recent years have tended to reduce the consumption of cadmium in plating but it still remains the largest use for cadmium. Cadmium-plated parts are used in the manufacture of automobiles, household appliances, aircraft, radios, television sets and electrical equipment.

The second-largest use is in the manufacture of pigments and chemicals. Cadmium sulphides give yellow-to-orange colours and cadmium sulphoselenides give pink-to-red and maroon. Cadmium stearates act as stabilizers in the production of polyvinyl chloride plastics, and cadmium phosphors are used for tubes in both black-and-white and colour television sets. The use of cadmium compounds in recent years has expanded at a rate of 5 to 10 per cent annually and is now the largest potential growth area. Unique photochemical properties have created new uses for cadmium in such areas as smoke alarm systems and solar energy cells. Expansion in these uses has more than made up for reduced consumption in plating.

Cadmium is a valuable alloying metal and has applications in cadmium-silver solders and cadmium-tin-lead-bismuth fusible or low-melting-point alloys for automatic sprinkler systems, fire-detection apparatus, and valve seats for high-pressure gas containers. Low-cadmium copper (about 1 per cent cadmium) is used in the manufacture of trolley and telephone wires because of the improved tensile strength imparted by cadmium. Low-cadmium copper is also now employed in automobile radiator finstock, replacing the low-silver copper formerly used. Another growing application is in the production of nickel-cadmium storage batteries. These batteries are considerably more expensive than the standard lead-acid battery, have a longer life and higher peak power output, are smaller, and are superior in low-temperature operation. They are especially suitable for use in airplanes, satellites and missiles, and ground equipment for polar regions, as well as in portable items such as battery-operated shavers, toothbrushes, drills and hand saws.

Prices

Typically, zinc plants pay for 60 per cent of the cadmium in zinc concentrates above a base level of 0.2 per cent cadmium equivalent to two kilograms of cadmium per tonne of zinc concentrate. Depending upon market conditions for cadmium and zinc concentrate, these payment terms can range from zero to 70 per cent of the full cadmium content.

In Canada, the *Northern Miner* publishes the announced sales price for cadmium, but does not publish a monthly average, and on this basis the price shown in Table 6 represents the price in effect at month-end.

Primary cadmium metal producers, including Canadian producers, normally sell metal at individually announced prices. Almost all Canadian metal production is exported to the United States and European Economic Community (EEC). North American prices, which are quoted on a delivered basis, are best represented by the "U.S. Producer" quotations published by *Metals Week* in New York. European prices, which

Table 4. Principal cadmium mine producers in Canada 1976 and (1975)

Company and Location	Daily Mill Capacity	Grade of Zinc Concentrates: Cadmium	Zinc	Lead	Copper	Silver	Zinc concentrate produced	Cadmium Content
	(tonnes ore)	(%)	(%)	(%)	(%)	(gm./tonne)	(tonnes)	(kgm.)
Newfoundland								
ASARCO Incorporated, Buchans	1 150 (1 150)	0.22 (0.22)	55.60 (55.16)	3.29 (3.40)	0.68 (0.69)	162.9 (143.3)	29 123 (32 008)	64 096.0 (70 418.7)
Newfoundland Zinc Mines Limited, Daniel's Harbour	1 350 (1 350)	0.17 (0.17)	62.0 (62.5)	.. (0.04)	.. (0.07)	.. (6.2)	61 213 (22 669)	104 063.3 (38 537.1)
New Brunswick								
Brunswick Mining and Smelting Corporation Limited, Bathurst	8 950 (8 950)	0.08 (0.07)	52.04 (51.95)	.. (2.69)	.. (0.33)	.. (92.6)	231 839 (321 446)	185 471.2 (224 986.8)
Heath Steele Mines Limited, Newcastle	3 650 (2 800)	0.09 (0.10)	48.34 (47.99)	1.83 (1.57)	0.75 (0.59)	122.7 (92.6)	72 422 (58 372)	65 181.0 (58 372.5)
Nigadoo River Mines Limited, Bathurst	1 050 (1 050)	0.65 (0.63)	45.30 (44.96)	2.41 (2.84)	1.09 (1.38)	167.3 (212.9)	8 970 (9 579)	58 304.5 (57 712.1)
Quebec								
Falconbridge Copper Limited, Lake Dufault Division, Noranda	1 400 (1 400)	0.11 (0.11)	52.82 (52.65)	.. (..)	.. (..)	.. (..)	23 523 (25 837)	25 875.9 (29 924.2)
Lemoine Mines Limited, Chibougamau	350 (—)	0.28 (—)	53.22 (—)	.. (—)	.. (—)	.. (—)	13 067 (—)	36 588.0 (—)
Mattagami Lake Mines Limited, Matagami	3 500 (3 500)	0.12 (0.13)	52.7 (53.1)	0.12 (..)	0.47 (0.48)	47.0 (43.2)	140 513 (147 179)	168 615.6 (191 333.6)
Orchan Mines Limited, Matagami	1 700 (1 700)	0.15 (0.11)	51.64 (52.09)	.. (..)	.. (..)	.. (..)	48 064 (28 717)	72 096.0 (31 589.0)

Table 4. (concl'd)

Company and Location	Daily Mill Capacity	Grade of Zinc Concentrates: Cadmium	Zinc	Lead	Copper	Silver	Zinc concentrate produced	Cadmium Content
	(tonnes ore)	(%)	(%)	(%)	(%)	(gm./tonne)	(tonnes)	(kgm.)
Ontario								
Falconbridge Copper Limited,	1 100	0.13	52.29	..	..	..	46 019	59 824.9
Sturgeon Lake Joint Venture, Sturgeon Lake	(1 100)	(0.15)	(52.44)	(0.59)	(0.97)	(103.9)	(42 825)	(64 237.5)
Mattabi Mines Limited,	2 700	0.14	54.36	..	..	..	126 185	176 659
Sturgeon Lake	(2 700)	(0.14)	(53.69)	(..)	(..)	(..)	(116 022)	(162 432.2)
Noranda Mines Limited,	4 550	0.37	52.07	..	0.82	54.9	56 584	209 360.8
Geco Division, Manitouwadge	(4 550)	(0.41)	(52.84)	(..)	(0.74)	(53.1)	(76 331)	(313 340.3)
Selco Mining Corporation Limited,	450	0.234	53.66	..	..	..	29 181	68 285.4
South Bay Division, Uchi Lake	(450)	(0.24)	(54.46)	(..)	(0.32)	(51.1)	(28 657)	(68 777.6)
Texasgulf Canada Ltd.	9 050	0.25	51.98	0.52	0.48	136.5	429 099	1 070 579.7
Kidd Creek mine, Timmins	(9 050)	(0.25)	(51.49)	(0.39)	(0.45)	(134.1)	(457 900)	(1 147 937.5)
Willroy Mines Limited,	1 450	0.17	51.58	..	0.46	..	20 482	35 001.8
Manitouwadge Division	(1 300)	(0.17)	(52.50)	(..)	(..)	(188.6)	(19 018)	(32 331.5)
Manitoba and Saskatchewan								
Hudson Bay Mining and Smelting	7 700	0.12	47.7	0.7	0.74	54.9	50 039	60 046.7
Co., Limited, Flin Flon	(7 700)	(0.12)	(48.6)	(1.0)	(0.80)	(54.9)	(49 565)	(59 543.7)
Sherritt Gordon Mines Limited,	2 700	0.13	49.41	..	0.90	..	17 354	22 559.6
Fox mine, Lynn Lake	(2 600)	(0.115)	(48.35)	(..)	(1.13)	(..)	(20 404)	(23 465.5)
Ruttan mine, Ruttan Lake	9 050	0.15	50.56	..	1.22	..	83 523	125 285.3
	(9 050)	(0.13)	(50.12)	(..)	(0.98)	(..)	(88 883)	(115 549.3)
British Columbia								
Cominco Ltd.,	9 050	0.13	48.1	5.8	..	78.9	150 648	195 844.6
Sullivan mine, Kimberley	(7 250)	(0.134)	(47.60)	(7.17)	(..)	(87.8)	(148 783)	(199 372.2)
H.B. mine, Salmo	1 100	0.44	53.8	2.0	..	27.4	23 261	102 350.1
	(1 100)	(0.42)	(53.2)	(2.2)	(..)	(24.0)	(22 884)	(96 459.7)

Kam-Kotia Mines Limited,	100	0.37	49.54	..	..	2 122.6	1 240	4 588.6
Silmonac mine, Sandon	(100)	(0.41)	(51.21)	(1.08)	(..)	(2 925.2)	(757)	(3 103.1)
Northair Mines Ltd.,	250	0.2	48.5	4.3	..	644.2	846	1 692.0
Alta Lake	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)
Teck Corporation Limited,	100	0.39	39.06	1.53	..	1 579.9	298	1 163.9
Beaverdell mine, Beaverdell	(100)	(0.54)	(38.12)	(1.63)	(..)	(1 974.8)	(239)	(1 304.5)
Western Mines Limited,	1 000	0.23	52.85	0.85	0.64	187.2	32 299	72 801.4
Lynx and Myra Falls, Buttle Lake	(1 000)	(0.23)	(52.40)	(0.9)	(0.6)	(165.9)	(31 222)	(70 372.9)
Yukon Territory								
	9 050 a)	0.06	51.36	1.59	..	..	114 868	68 921.3
Cyprus Anvil Mining	b)	0.04	28.94	15.65	..	90.5	24 622	9 849.0
Corporation,	(9 050) a)	(0.06)	(50.80)	(2.04)	(..)	(42.9)	(209 101)	(125 461.8)
Faro	b)	(0.04)	(29.34)	(18.37)	(..)	(195.4)	(69 957)	(27 982.4)
United Keno Hill Mines Limited,	450	0.67	48.0	..	..	..	586	3 926.3
Elsa	(450)	(0.73)	(51.53)	(..)	(..)	(..)	(556)	(4 052.9)
Northwest Territories								
Pine Point Mines Limited,	9 050	0.10	57.37	1.92	..	..	295 711	295 714.4
Pine Point	(9 050)	(0.10)	(57.93)	(1.87)	(..)	(..)	(273 468)	(273 470.9)
Nanisivik Mines Ltd.,	1 350	0.18	49.0	5.0	..	..	14 756	26 559.9
Baffin Island	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)

Source: Department of Energy, Mines and Resources, Ottawa; compiled from company reports.
— Nil; . . Not available

Table 5. Canada, cadmium production, exports and domestic shipments, 1965, 1970, 1974-76

	Production		Exports	Producers'
	All Forms[1]	Refined[2]	Cadmium Metal	Domestic Shipments
	(kilograms)			
1965	796 474	812 152	618 993	206 891
1970	1 954 055	836 745	702 630	157 307
1974	1 240 970	1 152 697	901 356	103 930
1975	1 191 674	1 142 502	637 797	104 898
1976[p]	1 292 000	1 342 269	1 555 772	123 389

Source: Statistics Canada.
[1]Production of refined cadmium from domestic ores, plus recoverable cadmium content of ores and concentrates exported; [2]Refined metal from all sources and cadmium sponge.
[p]Preliminary.

are quoted on a cif* port-of-discharge basis, with inland freight negotiable and dependent upon market conditions, are best represented by the "Commonwealth (cif)" quotations published by the *Metal Bulletin* in London. Price leadership in the United States is carried out by domestic producers, and Canadian price policy appears to adopt the U.S. basis. In the EEC, the "European Reference Price", cif/ex-works, also quoted by the *Metal Bulletin*, has formed the basis for some metal sales, as it represents the range of prices at which cadmium is sold by European producers, as determined by a regular survey conducted by the *Metal Bulletin*. Producer prices are very sensitive to dealer prices and tend to follow them closely, despite the fact that it is very difficult to determine the quantity of metal that they represent. The primary dealer quotations are the "N.Y. Dealer" quotations published by *Metals Week* and the "Sticks, free market" cif quotations published by the *Metal Bulletin*. All prices mentioned above represent cadmium metal having a minimum purity of 99.95 per cent and are set out in Table 6 which lists the monthly average during 1975, except for the "N.Y. Dealer" quotations which are the range of weekly averages during the month.

*Cost insurance freight.

Outlook

Based upon an average cadmium yield of 3.13 kilograms per tonne of zinc metal produced in the western world during the 1973-76 period, cadmium production in 1977 is estimated to be 13 146 tonnes, using a zinc metal forecast of 4 200 000 tonnes. Consumption in the western world is expected to be approximately in balance with production and some increase in price is possible, particularly, if a further decline in producer inventories of cadmium metal materializes during the year.

Table 6. Cadmium metal prices, 1976

	Northern Miner	Metals Week		Metals Bulletin	
Month	Cominco	U.S. Producer	New York Dealer	Common-wealth	Sticks, free Market
	($Cdn/lb)	($U.S./lb)		($U.S./lb)	
January	2.00	2.000	1.700-1.850	2.000	1.603-1.653
February	2.00	2.000	1.750-1.950	2.000	1.608-1.653
March	2.40	2.377	1.850-2.800	2.250	2.199-2.282
April	2.50	2.560	2.600-3.100	2.500	2.666-2.760
May	2.50	2.750	2.700-3.000	2.750	2.658-2.703
June	2.65	2.750	2.700-2.850	2.750	2.661-2.711
July	2.75	2.750	2.700-3.000	2.750	2.783-2,844
August	2.80	2.755	2.850-3.050	2.750	2.919-2.969
September	3.00	3.000	2.750-3.000	2.9375	2.8925-2.9425
October	3.00	3.000	2.500-2.850	3.000	2.617-2.701
November	3.00	3.000	2.450-2.600	3.000	2.524-2.582
December	3.00	3.000	2.350-2.550	3.000	2.346-2.428
Average 1976	2.633	2.662	2.408-2.717	2.641	2.456-2.519

Sources: *Northern Miner, Metals Week, Metals Bulletin.*

Table 7. Western world, cadmium metal production, 1974-76

Continent and Country	1974	1975	1976
		(tonnes)	
Europe			
Austria	26	30	51
Belgium	1 043	950	1 175
Finland	156	217	426
France	644	455	586
Germany	1 338	1 017	1 281
Italy	505	411	439
Netherlands	95	380	398
Norway	90	47	81
Spain	178	206	246
United Kingdom	273	254	190
Yugoslavia	140	150	152
	4 488	4 117	5 025
Africa			
S.W. Africa	114	100	83
Zaire	272	264	260
Zambia	13	8	7
	399	372	350
Asia			
India	59	53	56
Japan	3 025	2 688	2 502
	3 084	2 741	2 558
America			
Canada	1 152	1 142	1 342
Mexico	348	586	680
Peru	200	160	174
United States	3 024	1 989	1 663
Others	30	61	60
	4 754	3 938	3 945
Australia	759	552	648
Western World	13 485	11 720	12 500

Sources: World Bureau of Metal Statistics, Statistics Canada.

Tariffs

Canada

Item No.		British Preferential	GSP[1]	GATT[2]	General
32900-1	Cadmium in ores and concentrates	free	free	free	free
35102-1	Cadmium metal, not including alloys in lumps, powders, ingots or blocks	free	free	free	25%

United States

TSUS No.		GSP	GATT
601.66	Cadmium in ores and concentrates	free	free
632.14	Cadmium metal, unwrought, waste and scrap	free	free
632.84	Cadmium alloys, unwrought	free	free
633.00	Cadmium metal, wrought	free	free

European Economic Community Brussels Tariff Nomenclature Number		GSP	GATT
26.01	Cadmium in ores and concentrates	free	free
81.04	Cadmium metal: unwrought, waste and scrap	4%	4%
	Other	6%	6%

Japan

Brussels	Tariff Nomenclature Number	GSP	GATT
26.01	Cadmium in ores and concentrates	free	free
81.04	Cadmium metal: unwrought, waste and scrap, powders, flakes	free	8%
	Other	free	12%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States Annotated (TSUS); Official Journal of the European Communities, Common Customs Tariff; Customs Tariff Schedules of Japan.
[1]GSP — Generalized System of Preferences, extended to all, or most, developing countries. [2]GATT — General Agreement on Tariffs and Trade.

Calcium

M.J. GAUVIN

Calcium, a member of the alkaline earth family, is silvery white in colour, extremely soft and ductile, and has a low tensile strength. The metal tarnishes rapidly under atmospheric conditions and is a powerful reducing agent. It is the fifth most abundant element in the earth's crust, but does not occur naturally in its elemental form. Although calcium occurs chiefly in limestone, dolomite and sea water, high-calcium limestone deposits are the principal sources of calcium metal.

Metallic calcium may be recovered by electrolytic or thermal methods. Extraction was previously carried out by the fused salt electrolysis of calcium chloride, but today it is done only by aluminothermic reduction of lime by a non-continuous process. There are only three producers of metallic calcium in the noncommunist world: Chromasco Limited in Canada, Planet-Wattohm S.A., a subsidiary of Compagnie de Mokta, in France; and Charles Pfizer and Co. Inc. in the United States. All three use a thermal reduction method. Canada continued to be a leading international producer and supplier of calcium metal in 1976. Production and consumption of calcium amount to approximately 900 tonnes* a year in the noncommunist world. Calcium metal is also produced in the U.S.S.R, which exports small quantities to Western Europe and the United States.

Canadian industry

Chromasco Limited produces calcium metal at its metallurgical plant at Haley, near Renfrew, Ontario. It utilizes the same vacuum retort method, known as the "Pidgeon process", which is used to produce its principal product, magnesium. Other products from the Haley operation, in addition to magnesium and calcium

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, calcium production and exports, 1975-76

	1975		1976[p]	
	(kilograms)	($)	(kilograms)	($)
Production (metal)[1]	428 288	1 004 674	558 000	1 521 000
Exports (metal)				
United States	262 629	559 000	261 722	675 000
India	—	—	11 929	55 000
West Germany	7 302	24 000	11 339	42 000
South Africa	—	—	7 257	26 000
Mexico	34 563	63 000	—	—
Other countries	5 264	25 000	5 763	24 000
Total	309 758	671 000	298 010	822 000

Source: Statistics Canada.
[1]Calcium metal and calcium used in production of calcium alloys.
— Nil; [p]Preliminary.

metals, are magnesium and calcium alloys, and barium, strontium and thorium metals. To make calcium, high-purity quicklime (CaO) and commercially pure aluminum are briquetted and then charged into horizontal electric retorts made of chrome-nickel steel. Under vacuum, and at a temperature of about 1170°C, the aluminum reduces the quicklime to form a calcium vapour. This calcium vapour crystallizes at about 680°-740°C in the water-cooled condenser section of the retort, which projects outside the furnace wall. The initial product, known as "crowns", grades about 98 per cent calcium. Higher purities are obtained by subsequent refining operations.

Chromasco makes four main grades of calcium: Grade 1, chemical standard, 99.7 per cent calcium with up to 0.2 per cent magnesium and minor amounts of other elements; Grade 2, nuclear quality, 99.4 per cent calcium with magnesium up to a maximum of 0.5 per cent; Grade 3, battery grade, 98.5 per cent calcium with a maximum of 0.5 per cent magnesium, 0.15 per cent nitrogen maximum, and 0.45 per cent aluminum maximum; Grade 4, commercial crowns, 98.0 per cent calcium, 0.5 to 1.5 per cent magnesium, 0.15 per cent nitrogen maximum, 0.45 per cent aluminum maximum.

Canadian production of calcium in 1976 was 558 000 kilograms. Most of the production is exported, 298 010 kilograms being sold in foreign markets in 1976, compared with 309 758 kilograms in 1975. Exports to the United States totalled 261 722 kilograms in 1976, compared with 262 629 kilograms in 1975.

Uses

Metallic calcium is a powerful reducing agent. Accordingly, one of its major applications is in metallurgical processes for removing oxygen and halogens from various metals which resist reduction by normal reductants such as carbon, hydrogen and natural gas. Among such metals are columbium, tantalum, titanium, thorium, uranium, vanadium and zirconium. As a purifier, calcium removes residual sulphur, phosphorus and oxygen from steel. The major usage of calcium is to remove bismuth, antimony and arsenic from lead. Metallic calcium is also used in producing organocalcium compounds for special lubricants, corrosion inhibitors and detergents, and to form alloys with magnesium, aluminum, lead, lithium and silicon. In certain types of storage batteries, a lead alloy containing only 0.1 per cent calcium exhibits properties superior to an alloy containing the 3 per cent antimony generally used. These new storage batteries do not require the addition of any water. Alloys of calcium and silicon, and of calcium, silicon and magnesium, are widely used in the steel industry to control grain size, inhibit carbide formation, improve ductility and reduce internal flaws.

Table 2. Canada, calcium production and exports, 1965, 1970 and 1974-76

	Production[1]	Exports
	(kilograms)	
1965	72 318	67 267
1970	201 194	78 970
1974	476 084	339 060
1975	428 288	309 758
1976[p]	558 000	298 010

Source: Statistics Canada.
[1]Calcium metal, and calcium metal used in production of calcium alloys.
[p]Preliminary.

Outlook

Consumption of calcium metal is limited, and unless its use is greatly accelerated, existing producers will be able to supply the market adequately in the foreseeable future. The growth rate in calcium consumption should rise as the usage of "maintenance free" automotive batteries continues to grow. These hermetically sealed batteries use calcium-lead alloy instead of antimonial-lead alloy in the battery grids and require no addition of water during the life of the battery.

Prices

The price of calcium metal crowns was $1.33 a pound throughout the year. The price of calcium silicon alloy was reduced from 57 cents a pound to 51 cents a pound in January. This price was maintained for the remainder of the year. According to *Metals Week*, December 27, 1976, United States prices were as follows:

	¢/lb
Calcium metal, ton lots, full crowns	133
Calcium alloy, fob shipping point, freight equalized to nearest main producer, carload lots:	
Calcium silicon, 32% calcium	51

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(% ad. val.)			
92805-1	Calcium metal	10	15	25	10

United States

Item No.		On and after January 1 1971	1972
		(% ad. val.)	
632.16	Cacium metal, unwrought	9	7.5
633.00	Calcium metal, wrought	10.5	9

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976) T.C. Publication 749.

Cement

D.H. STONEHOUSE

Portland cement is produced by burning, usually in a rotary kiln, an accurately proportioned, finely ground mixture of limestone, silica, alumina and iron oxide. Kiln discharge, in the shape of rough spheres, is a fused, chemically complex mixture of calcium silicates and aluminates, termed clinker; which is mixed with gypsum, 4 to 5 per cent by weight, and ground to a fine powder to form portland cement. By close control of the raw mix, the burning conditions and of the use of additives in the clinker-grinding procedure, finished cements displaying various desirable properties can be produced.

The three basic types of portland cement are produced by most Canadian cement manufacturers — Normal Portland, High-Early-Strength Portland and Sulphate-Resisting Portland. Moderate Portland Cement and Low-Heat-of-Hydration Portland Cement, designed for use in concrete to be poured in large masses such as in dam construction, are manufactured by several companies in Canada. Masonry cement (generic name) includes such proprietary names as Mortar Cement, Mortar Mix (unsanded), Mason's Cement, Brick Cement and Masonry Cement. The latter, produced by portland cement manufacturers, is a mixture of portland cement, finely ground high-calcium limestone (35 to 65 per cent by weight) and a plasticizer. The other products do not necessarily consist of portland cement and limestone, and may include a mixture of portland cement and hydrated lime and/or other plasticizers.

Cement has little use alone but, when combined with water, sand, gravel, crushed stone or other aggregates in proper proportions, acts as a binder, cementing the materials together as concrete. Concrete has become a widely used and readily adaptable building material which can be poured on site in large engineering construction projects, or used in the form of delicate precast panels or heavy, prestressed columns and beams, in building construction.

Specifications

Portland cement used in Canada should conform to the specifications of CSA Standard A5 — 1971 published by the Canadian Standards Association. This standard covers the five main types of portland cement as follows: Normal, Moderate, High-Early-Strength, Low-Heat-of-Hydration, and Sulphate-Resisting Portland cements. Masonry cement produced in Canada should conform to the CSA Standard A8 — 1970.

The cement types manufactured in Canada that are not covered by the CSA standards generally meet the appropriate specifications of the American Society of Testing and Materials (ASTM).

Cembureau, The European Cement Association, has published *Cement Standards of the World — Portland Cement and its Derivatives,* in which standards are compared. Cembureau's *World Cement Directory* lists production capacities by company and by country.

Summary

Cement is one of a number of industrial mineral commodities produced in Canada in direct support of the construction industry. Others are clays, lime, sand and gravel, stone, asbestos and gypsum. The construction industry is the largest single employer in Canada and one that is immediately affected by changes in the country's economic climate.

In Canada construction is categorized broadly as building construction and engineering construction, and the values of each type, discounted by inflationary factors, provide a basis for comparison of annual construction in place. Historically, building construction has represented about 60 per cent of the total value of construction and one element within this general category — residential construction — has normally accounted for 30 per cent of total value, or one half of building construction. In current dollars, construction is credited with about 17 per cent of gross national expenditure. In 1976 capital and repair expenditure on construction was $32 billion, up about 12 per

The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

cent over expenditures in 1975. Wages and material costs increased at about 13 per cent and 9 per cent respectively. Labour unrest, mainly in the Atlantic, Quebec and British Columbia regions, caused less lost time in the construction industry than in 1975. The Anti-Inflation Board, constituted late in 1975, produced mixed reactions during its first full year of operation. Unquestionably, wage and price increases were moderated but an atmosphere of uncertainty prevailed throughout the business community and in many instances corporate decisions to forego, or to at least defer, construction of new or expanded facilities were influenced by that uncertainty.

Building construction, particularly the residential sector, remained strong during 1976. Housing starts, an indicator of current and future construction activity, increased 18 per cent over 1975 to 273 203 units.

In a supply role to a volatile industry, the cement industry, in turn, must be capable of adjusting and remaining competitive. Markets and raw material adequacy generally have influenced the selection of new cement plant sites. However, environmental considerations, labour situations and energy sources are becoming important factors in planning industry expansion and in keeping some plants operative. A coal-burning capability will probably become increasingly attractive

Table 1. Canada, cement production and trade, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
By province				
Ontario	3 800 386	110 707 436	3 764 000	116 162 000
Quebec	3 292 546	101 788 856	2 683 000	88 733 000
British Columbia	888 082	34 801 055	919 000	38 499 000
Alberta	876 897	29 347 446	1 048 000	36 948 000
Manitoba	457 383	17 056 376	586 000	22 606 000
Saskatchewan	222 523	9 859 775	327 000	15 171 000
New Brunswick	. .	5 839 443	. .	8 967 000
Nova Scotia	. .	6 094 024	. .	7 059 000
Newfoundland	. .	4 678 129	. .	5 014 000
Total	9 965 111	320 172 540	9 850 000	339 159 000
By type				
Portland	9 606 367	. .	9 485 550	. .
Masonry[2]	358 744	. .	364 450	. .
Total	9 965 111	320 172 540	9 850 000	339 159 000
Exports				
Portland cement				
United States	981 583	23 229 000	920 020	23 921 000
Other countries	14 996	673 000	104	6 000
Total	996 579	23 902 000	920 124	23 927 000
Cement and concrete basic products				
United States	. .	11 580 000	. .	14 930 000
Other countries	. .	413 000	. .	654 000
Total	. .	11 993 000	. .	15 584 000
Imports				
Portland cement, white				
United States	23 492	1 310 000	25 299	1 373 000
Belgium and Luxembourg	55	5 000	569	29 000
Japan	248	14 000	565	25 000
Total	23 795	1 329 000	26 433	1 427 000

Table 1. (concl'd)

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Cement, nes[3]				
United States	396 733	16 671 000	286 980	13 323 000
United Kingdom	474	68 000	988	45 000
West Germany	16	8 000	177	13 000
Yugoslavia	—	—	100	12 000
Bahamas	—	—	1	. . .
France	184	58 000	—	—
Total	397 407	16 805 000	288 246	13 393 000
Total cement imports	421 202	18 134 000	314 679	14 820 000
Refractory cement and mortars				
United States	. .	5 283 000	. .	6 048 000
Austria	. .	16 000	. .	111 000
United Kingdom	. .	159 000	. .	56 000
Ireland	. .	299 000	. .	33 000
West Germany	. .	8 000	. .	30 000
Other countries	. .	57 000	. .	44 000
Total	. .	5 822 000	. .	6 322 000
Cement and concrete basic products, nes				
United States	. .	1 991 000	. .	2 261 000
United Kingdom	. .	7 000	. .	69 000
West Germany	. .	25 000	. .	34 000
Mexico	. .	2 000	. .	2 000
Italy	. .	36 000	. .	1 000
Total	. .	2 061 000	. .	2 367 000
Cement clinker				
United States	7 576	208 000	14 365	376 000

Source: Statistics Canada.
[1]Producers' shipments, plus quantities used by producers. [2]Includes small amounts of other cements. [3]Includes grey portland, masonry, acid proof, aluminous and other specialty types of cement.
p Preliminary; nes Not elsewhere specified; . . Not available — Nil; . . . Less than $1 000.

as oil and gas become more expensive. The cement manufacturing industry uses an average of 5.5 million Btu's to produce a ton of product and is considered to be one of a number of energy-intensive industries. In fairness, the real product is concrete and the energy consumed over the entire life cycle of concrete structures can compare favourably with the amount consumed over the life cycle of structures built with other materials. The cement industry in Canada has voluntarily set an energy conservation goal — a reduction by 1980 of 12 per cent in unit energy consumption, with 1974 as a base year.

Markets for cement tend to be regional because transportation costs represent much of the laid-down price to the consumer and only rarely, as in the case of special cements or in periods of regional shortage, are shipments made beyond normal distribution boundaries. Production, therefore, is determined by the regional construction activity and by interpretation of construction intentions.

An export market for Canadian cement developed in the northeastern and southeastern United States during the early 1970s because of a production deficiency in those regions. Canadian production became influenced, at least regionally, by construction activity and intentions in that country. The lack of production capability was brought on by plant closures forced by the application of environmental legislation, and by the lack of appeal the industry has had to attract capital investment for either the erection of new plants or the modernization of existing plants. During 1974 and 1975 a depressed construction industry in the United States gave temporary and partial relief from the cement shortage situation which has seen imported cement accepted from as far away as Norway. Throughout 1976 the construction industry continued to improve but at a much slower rate than was anticipated.

In addition to spot sales of cement and clinker in the United States from Canadian plants, at least three contracts to supply major amounts of clinker to U.S. cement companies exist. Whether this will develop into a trend in the face of high energy costs and changing priorities in the utilization of fossil fuels remains to be seen. The opportunity to import energy in the form of cement clinker, while avoiding the environmental problems associated with kiln operations, could become attractive. Net capacity increase in the U.S. cement industry in 1976 was about 2 million short tons. Although the industry is recovering from the setbacks of the early 1970s it is unlikely that any new or expanded capacity in the United States through the next two or three years will do any more than meet demand.

Cement production capacity in Canada at the end of 1976 was about 15 million tonnes a year, excluding the capacity of five clinker grinding plants, two of which (belonging to Canada Cement Lafarge Ltd.), have recently been relegated to that category from that of fully integrated cement producing plants. During 1976, capacity changes indicate a net reduction of 77 000 tonnes a year despite the addition of 596 000 tonnes a year by St. Marys Cement Limited at its St. Marys, Ontario plant, where a four-stage suspension preheater and new kiln were added during the conversion from a wet to a dry process. The rehabilitation and conversion of the Canada Cement Lafarge Ltd. Montreal East plant was slowed because of market conditions, with the result that at year-end the clinker-producing capacity was nonexistent and the plant could be used for grinding only. Various adjustments to the listed capacities of plants under Genstar Limited were made.

Doubling the capacity of the Brookfield, Nova Scotia plant of Canada Cement Lafarge Ltd. will be the only major addition to total industry capability during 1977. Ocean Cement Limited continued construction of its new facility on Tilbury Island (Vancouver), B.C. with 1978 as a completion target date. Inland Cement Industries Limited began a $60 million expansion program at its Edmonton, Alberta plant with the addition of new environmental protection equipment. The total program will be completed in the early 1980s and will increase capacity by about 75 per cent. In October 1976 St. Lawrence Cement Company announced acquisition of Ciment Independant Inc. including the cement plant at Joliette, Quebec, a construction division, four ready-mix plants and two crushed-stone operations. Early in 1977 the company completed the purchase of all assets of Universal Atlas Cement Division's plant at Hudson, New York for $8.2 million. Universal Atlas Cement is a division of United States Steel Corporation.

Canadian industry and developments

Atlantic region. There are three cement-manufacturing plants in the Atlantic provinces serving the markets in the immediate area by road, rail and water transportation routes. The plants represent 4.8 per cent of Canadian cement production capacity in a region having 9.5 per cent of the total population of Canada.

A plant at Corner Brook, Newfoundland, established in 1951, is operated by North Star Cement Limited. Limestone and shale, raw materials for the dry process being used, are quarried in the immediate area, and gypsum is purchased from Flintkote Holdings Limited, which quarries gypsum at Flat Bay, about 60 miles south of Corner Brook. Shipments of portland cement are made, mainly by rail and truck to provincial markets. Output depends directly on construction activity.

During 1974 Lehigh Portland Cement Company, Allentown, Pennsylvania, in joint agreement with British Newfoundland Exploration Limited (Brinex), assessed the raw materials available in the Port au Port district of Newfoundland with the objective of establishing a 1-million-tonne-a-year portland cement facility in the region. Obviously, a buoyant export market for portland cement or for clinker would be needed in order to support a plant of such capacity. Early in 1975 Lehigh terminated its association with the project while Brinex continued to investigate the feasibility of an industrial mineral complex based on high-calcium limestone. Canada Cement Lafarge Ltd. maintains an active interest in a large, high-calcium limestone deposit in the vicinity of Port au Port.

Nova Scotia's only cement manufacturing facility, a single-kiln, dry-process plant incorporating the most

Table 2. Canada, cement production, trade and consumption, 1965, 1970, 1974-76

	Production[1]	Exports[2]	Imports[2]	Apparent Consumption[3]
	(tonnes)			
1965	7 645 483	303 804	34 127	7 375 806
1970	7 208 413	513 939	88 170	6 782 644
1974	10 585 105[r]	1 148 393	251 300	9 688 012[r]
1975	9 965 111	996 579	421 202[r]	9 389 734[r]
1976[p]	9 850 000	920 124	314 679	9 244 555

Source: Statistics Canada.
[1]Producers' shipments, plus quantities used by producers. [2]Does not include cement clinker. [3]Production, plus imports, less exports.
[p]Preliminary; [r]Revised.

modern analytical and control devices, was established in 1965 by Canada Cement Company, Limited (now Canada Cement Lafarge Ltd.) at Brookfield. Limestone at the plant site is chemically very close to a natural cement rock; but variations in lime, alumina and iron content necessitate the addition of iron oxide, coal ash and high-calcium limestone, all of which are available nearby. Gypsum is purchased from the Milford quarry of National Gypsum (Canada) Ltd., about 25 miles south of Brookfield. Portland cement is marketed in bulk or package under the brand name "Maritime" cement. During 1975 work began on a $25 million expansion program which will double the present plant capacity by 1978 with the installation of a second kiln.

Canada Cement Lafarge Ltd. also operates a cement-manufacturing plant at Havelock, New Brunswick. This plant was built in 1951 and expanded in 1966 by the addition of a second kiln. The company increased plant capacity with the addition of heavier grinding equipment and larger storage facilities in 1974 and now has a capacity of 327 000 tonnes a year.

Quebec. In the Province of Quebec five companies operate a total of seven cement manufacturing plants. Regionally, the companies producing cement in Quebec compete for the construction markets in the Montreal and Quebec City areas as well as for markets in more remote regions where major heavy construction projects such as the James Bay hydroelectric project, and iron ore development north of Port-Cartier continued through 1976. Preparations for the 1976 Olympics added to construction activity in Montreal, but projections indicate slower growth during 1977. Major export markets in the United States, developed over the past few years for both cement and cement clinker, accepted less product in 1976. The recovery of the construction industry in that country was more sluggish than anticipated.

The Montreal East plant of Canada Cement Lafarge Ltd. at Pointe-aux-Trembles has been operated as part of the Canada Cement complex since it was acquired in 1909. Material from the adjacent quarry approximates a natural raw mix which requires only minor amounts of sand, iron oxide and high-calcium limestone for corrective purposes. Situated a mile from docking facilities on the St. Lawrence River, the plant has access to water transportation. Rehabilitation of the Montreal East plant began in 1976. Plans to replace seven old, wet-process kilns with two dry-process, preheater-equipped kilns was to result in an effective total capacity at completion of the project of about 454 000 tonnes a year. At the end of 1976 the plant was serving only as a grinding plant because market conditions had slowed the conversion project.

Canada Cement Lafarge's plant at St. Constant, south of Montreal, is modern, technically efficient and, with a capacity of over 950 000 tonnes a year, is currently supplying product to fill the company's sales contracts in the Quebec region. The company's Hull operation, on the site where cement was first produced in Canada, was closed as a producing facility at the end of 1975. The plant has not been dismantled and is currently serving as a distribution terminal with grinding capability.

Miron Company Ltd. operates a dry-process plant at St-Michel. The company also supplies concrete and other building materials to the construction industry, and maintains a contracting division. During 1973 Genstar Limited of Montreal acquired the majority of Miron shares. Genstar, through its cement division, operates Inland Cement Industries Limited in Winnipeg, Regina and Edmonton, and Ocean Cement Limited in Bamberton, B.C.

St. Lawrence Cement Company has a plant at Villeneuve, near Quebec City, capable of manufacturing about 700 000 tonnes of cement a year. Limestone and shale are available at the site, iron oxide and gypsum are brought in. Finished products include normal portland cement, medium-heat-of-hydration cement and masonry cement. Shipments are made in bulk or in bags by truck, rail and ship. During 1976 St. Lawrence acquired the Joliette cement plant of Independent Cement Inc. together with its construction, ready-mix and crushed-stone divisions.

Independent Cement Inc. began construction of its cement-manufacturing plant at Joliette, Quebec in 1965 and went on stream in 1966 with a two-kiln operation capable of producing about 400 000 tonnes a year. Two new kilns were added in the early 1970s and, at takeover, St. Lawrence announced the capacity to be over 1 million tonnes a year.

Ciment Quebec Inc. was established in 1952 at St-Basile, 40 miles west of Quebec City, as a single-kiln operation. Two additional kilns were installed to boost production capacity to about 345 000 tonnes a year.

Ontario. Four companies operate a total of six cement-manufacturing plants in the Ontario region, serving industrial and urban growth areas in southern Ontario and shipping to points in Quebec and northern Ontario as well as the United States. One other company operates a clinker-grinding plant.

The industrialized and population-intense region surrounding Lakes Ontario and Erie continues to grow and, in so doing, provides markets for cement in many engineering, commercial, industrial and residential building projects, all of which have shown continued growth. The Ontario cement producers represent 43.7 per cent of total production capacity in a region occupied by about 36 per cent of the total Canadian population. Steady growth is indicated by continued investment in additional capacity.

Lake Ontario Cement Limited is one of Canada's largest cement exporters. The plant is located at Picton, where favourable raw materials are situated adjacent to deep water, permitting comparatively inexpensive bulk shipments to Great Lakes and St. Lawrence Seaway ports. Shipments, also made by truck and rail to domestic markets, continued at an all-time high in

Table 3. Cement plants — approximate annual capacities, end of 1976

Company	Plant Location	Process	Capacity
Atlantic region			
1 North Star Cement Limited	Corner Brook, Nfld.	dry	159 000
2 Canada Cement Lafarge Ltd.	Brookfield, N.S.[4]	dry	236 000
3 Canada Cement Lafarge Ltd.	Havelock, N.B.	dry	327 000
Total Atlantic Region			722 000
Quebec			
4 Canada Cement Lafarge Ltd.	Hull[5]		
5 Canada Cement Lafarge Ltd.	Montreal East[5]		
6 Canada Cement Lafarge Ltd.	St. Constant	dry	953 000
7 Ciment Quebec Inc.	St. Basile	wet	345 000
8 Independent Cement Inc.	Joliette[2]	dry	1 089 000
9 Miron Company Ltd.	St. Michel[3]	dry	953 000
10 St. Lawrence Cement Company	Villeneuve	wet	714 000
Total Quebec Region			4 054 000
Ontario			
11 Canada Cement Lafarge Ltd.	Woodstock	wet	540 000
12 Canada Cement Lafarge Ltd.	Bath	dry	998 000
13 Lake Ontario Cement Limited	Picton	dry	1 515 000
14 Medusa Products Company of Canada, Limited	Paris[1]		
15 St. Lawrence Cement Company	Clarkson	wet/dry	1 588 000
16 St. Marys Cement Limited	Bowmanville	wet	635 000
17 St. Marys Cement Limited	St. Marys[6]	dry	1 270 000
Total Ontario Region			6 546 000
Manitoba			
18 Canada Cement Lafarge Ltd.	Winnipeg	wet	572 000
19 Inland Cement Industries Limited	Winnipeg[3]	wet	295 000
Saskatchewan			
20 Canada Cement Lafarge Ltd.	Floral[1]		
21 Inland Cement Industries Limited	Regina[3]	dry	204 000
Alberta			
22 Canada Cement Lafarge Ltd.	Exshaw	dry	726 000
23 Canada Cement Lafarge Ltd.	Edmonton[1]		
24 Inland Cement Industries Limited	Edmonton[3]	wet	570 000[7]
Total Prairie Region			2 367 000
British Columbia			
25 Canada Cement Lafarge Ltd.	Lulu Island	wet	558 000
26 Canada Cement Lafarge Ltd.	Kamloops	dry	190 000
27 Ocean Cement Limited	Bamberton[3]	wet	550 000
28 Ocean Cement Limited	Tilbury Island[3]	dry	998 000[8]
Total British Columbia Region			1 298 000
Total Capacity			14 987 000

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Grinding plants only. [2]Controlled by St. Lawrence Cement Company. [3]Controlled by Genstar. [4]Capacity to be doubled by 1977. [5]At end of 1976 facilities available for grinding only. [6]Capacity increased during 1976. [7]Expansion program under way. [8]Not included in totals — under construction.

1976. The company's plant expansion program was completed in 1975 with the addition of a new preheater kiln which doubled the plant capacity. In early-1976 Lake Ontario made the first shipment of 18 000 tons of clinker to Martin Marietta Corporation at Bay City, Michigan as part of a $20 million, three-year contract.

The Belleville plant of Canada Cement Lafarge Ltd., one of the original operations grouped to form the Canada Cement Company in 1909, was phased out of operation at the end of October, 1973, subsequent to the company's new plant at Bath commencing start-up procedures in mid-September.

Canada Cement Lafarge operates a plant at Woodstock, Ontario capable of producing about 540 000 tonnes a year from a two-kiln, wet process. The plant was constructed in 1956 to serve the developing area of southwestern Ontario. Clay overburden from the limestone quarry is of a quality that can be utilized in manufacturing masonry cement, high-early-strength cement and normal portland cement.

St. Lawrence Cement Company built its Clarkson, Ontario plant in 1957 and with the expansion to 1.58 million tonnes a year in 1968 it became Canada's largest producing plant. The plant now combines a wet and a dry process.

Limestone for the plant is brought by boat from Ogden Point, 100 miles east of Toronto on the north shore of Lake Ontario. A mile-long, overhead, covered conveyor is used to transport stone from the lake carriers to the plant. Gypsum is trucked from producers in southwestern Ontario. The market area for finished cement product is mainly the Toronto-Hamilton strip and southern Ontario, served by rail and truck deliveries. Large quantities of clinker are exported to United States points. The company sold its assets in Wyandotte Chemical Corporation, Michigan in compliance with a U.S. Federal Trade Commission divesture order issued in early-1973.

St. Marys Cement Limited operates two plants in Ontario. The original plant at St. Marys was constructed in 1912 to serve the Toronto area. It has been expanded and modernized over the years and, with the installation of a sixth kiln and four-stage suspension preheater in 1976, will have the capacity to produce over 1.2 million tonnes a year. A new and highly automated plant, built at Bowmanville during 1967 and 1968, was expanded during 1973 with the addition of a second kiln to increase capacity to ship product via truck and rail to the major marketing area of Metropolitan Toronto.

Medusa Products Company of Canada, Limited, Paris, Ontario grinds a white clinker imported from the Medusa plant at York, Pennsylvania. The white cement is sold mainly in Ontario.

Prairie region. Two companies, Canada Cement Lafarge Ltd. and Inland Cement Industries Limited, operate a total of five clinker-producing plants in the Prairie region along with two clinker-grinding plants. The region accounts for 15.7 per cent of Canadian cement-producing capacity exclusive of the grinding plants and during 1976 produced at about 80 per cent of that capacity.

Canada Cement Lafarge Ltd. operates a cement-manufacturing plant at Fort Whyte, near Winnipeg, Manitoba. The original facility has been enlarged and rebuilt several times and is today a highly efficient plant capable of producing about 570 000 tonnes of cement a year. High-calcium limestone is obtained from the company's quarry at Steep Rock on the shore of Lake Manitoba, gypsum from Windermere, B.C., silica from Beausejour and clay from Fort Whyte. Products include portland cement, sulphate-resisting cement, oil-well cement and masonry cement for a market area extending from the United States border to the most northerly populated areas, and eastward halfway across northern Ontario.

At Exshaw, Alberta a cement plant has been operated by the Canada Cement group since 1910. A modernization and expansion program was completed in 1975 with the installation of a new kiln. The program included the development of a new quarry and the

Table 4. Canada, cement plants, kilns, production and capacity, 1972-1976

	Plants	Kilns	Approximate Capacity	Production[1]	Capacity Utilization
			(tonnes a year)	(tonnes)	%
1972	24	59	13 560 000	9 037 840	67
1973	24	58	14 268 000	9 873 856	69
1974	24	58	14 404 000	10 258 506	71
1975	24	57	15 064 000	9 764 086	65
1976	22	50	14 987 000	9 850 000	66

Sources: Statistics Canada and company data
[1]Production is preliminary in each case and does not include clinker

Table 5. Canada, destination of domestic cement shipments[1], 1976

	(tonnes)
Ontario	3 245 643
Quebec	2 093 957
Rest of Canada	3 448 996
Canada Total	8 788 596
Exports	758 476
Total Shipments	9 547 072

Source: Statistics Canada.
[1]Special compilation. Direct sales from producing plants.

relocation of several roads and structures in Exshaw. Production capacity is now 726 000 tonnes a year. Finished cement is shipped by rail and truck, mainly to consumers in Alberta and western Saskatchewan. Large quantities of clinker are shipped to the company's grinding, storage and distributing plant at Edmonton, Alberta. A facility at Floral, near Saskatoon, Saskatchewan was built in 1964 as a distribution terminal and in 1966 was expanded to include clinker-grinding equipment. When the demand for cement warrants, the Floral establishment can be expanded further to become a fully integrated cement-manufacturing and distributing plant.

Inland Cement Industries Limited, a Genstar Limited subsidiary, operates three cement-manufacturing plants, one in Winnipeg, Manitoba; one in Regina, Saskatchewan and one in Edmonton, Alberta. The Winnipeg plant came on stream in 1965 to increase the company's total production capacity to over 900 000 tonnes a year. A limestone quarry at Mafeking, Manitoba, near the Manitoba — Saskatchewan border, supplies limestone to the Regina plant, while the Winnipeg plant is supplied from Steep Rock. The Edmonton plant is supplied from Cadomin, Alberta, by a 5000-ton unit train which provides an automated materials-handling system. Other raw materials are obtained close to the plant sites. A $60 million expansion of the Edmonton plant began in 1976 with the addition of new environmental control facilities. The program, when completed in the early 1980s will result in a 75 per cent increase in capacity. A market area

Table 6. Canada, mineral raw materials[1] used by the cement industry

Commodity	1974	1975[p]
	(tonnes)	
Limestone	14 447 790	12 951 410
Clay	864 308	814 411
Shale	482 358	693 862
Gypsum	509 877	454 159
Sand	269 142	295 300
Iron oxide	93 230	100 469

Source: Statistics Canada.
[1] Includes purchased materials and material produced from own operations.
[p] Preliminary.

Table 7. Capacity changes during 1976, cement plants

Company	Plant Location	Net capacity increase compared with end of 1975	Approximate cost	Remarks
		(tonnes a year)	($ million)	
Quebec				
Canada Cement Lafarge Ltd.	Montreal East	(907 000)	. .	Conversion from wet to dry process, replacement of 7 kilns with 2 for effective capacity of 500 000, slowed by market conditions. Available only as clinker — grinding plant at end of 1976.
	Hull			Available as clinker-grinding facility only at end of 1976.
Ontario				
St. Marys Cement Limited	St. Marys	596 000	30	Doubling of plant capacity with new dry kiln and four-stage suspension preheater.
Adjusted capacities		234 000		Published company data necessitated changes in recorded capacity of 5 plants
Net change 1976 over 1975		(77 000)		

Source: Mineral Development Sector, Department of Energy, Mines and Resources Ottawa.
. . Not available.

Table 8. Planned capacity changes (as of early 1977)

Company	Plant location	Net Capacity Change compared with Table 3	Expected date of completion	Approximate cost	Remarks
		(tonnes a year)		($ million)	
Atlantic					
Canada Cement Lafarge Ltd.	Brookfield, N.S.	238 000	1977	25	Capacity to be doubled.
Quebec					
Canada Cement Lafarge Ltd.	Montreal East	. .	. .	. .	Market conditions have slowed plant conversion. Serving as grinding plant only at end of 1976.
Alberta					
Inland Cement Industries Limited	Edmonton	430 000	. .	60	New dry-process kiln and electrostatic precipitator system to be installed.
British Columbia					
Ocean Cement Ltd.	Vancouver	1 000 000	1978	90	New plant under construction on Tilbury Island.
	Bamberton	(635 000)	1978	. .	Clinker production to be phased out.
Total		1 033 000		175	

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
. . Not available.

stretching east to the Lakehead and west to, and including. British Columbia is served by Inland's facilities.

Houg Cement, Limited, Edmonton was scheduled to produce cement from marl early in 1974 near Clyde, some 40 miles northeast of Edmonton. Details are limited, but a $5 million expenditure for a 60 000-tonne-a-year plant has been reported. Local markets would consist principally of ready-mix operations.

Pacific region. Construction activity in British Columbia has been maintained at a high level despite labour difficulties and escalating costs. The optimistic outlook towards increased activity in construction was reflected in Genstar's decision to build a 680 000 tonne-a-year plant in the Vancouver area and amplified by the company's further commitment to increase the size of this plant to about 1-million tonnes even before construction had begun. The new plant will be located on Tilbury Island and will cost an estimated $90 million. Inland Cement Industries Limited and Ocean Cement Limited, are operated as a cement division of Genstar. Ocean Cement quarries limestone at Bamberton on Vancouver Island for cement manufacture and for use as an aggregate. The cement plant, with a capacity of about 550 000 tonnes a year, will be phased out upon completion of the new facility on the mainland.

Canada Cement Lafarge Ltd. produces cement at Richmond on Lulu Island near Vancouver, British Columbia using limestone barged down the Strait of Georgia from a quarry at Vananda on Texada Island.

The plant was built in 1958, and later the capacity was doubled to the present 558 000 tonnes a year. A new plant with a capacity of over 190 000 tonnes a year began production in 1970 at Kamloops, British Columbia.

Markets and trade

Cement markets are regional in scope and are centred in developing urban areas where construction activity is concentrated, or in areas where mining or heavy

Table 9. Canada, house construction, by province

	Starts			Completions			Under Construction		
	1975	1976	% Diff.	1975	1976	% Diff.	1975	1976	% Diff.
Newfoundland	5 342	5 709	+7	4 831	5 850	+21	5 107	4 537	−11
Prince Edward Island	847	842	−1	1 130	989	−12	314	183	−42
Nova Scotia	6 366	7 470	+17	6 249	7 364	+18	7 301	7 307	+0
New Brunswick	6 983	6 772	−3	5 804	7 137	+23	4 463	3 873	−13
Total (Atlantic Provinces)	19 538	20 793	+6	18 014	21 340	+18	17 185	15 900	−8
Quebec	54 741	68 748	+26	51 540	54 301	+5	31 805	43 600	+37
Ontario	79 968	84 682	+6	81 865	80 302	−2	75 690	78 359	+4
Manitoba	7 845	9 339	+19	8 760	8 492	−3	4 917	5 820	+18
Saskatchewan	10 505	13 143	+25	7 705	11 046	+43	7 728	9 319	+21
Alberta	24 707	38 771	+57	17 550	25 858	+47	16 909	29 411	+74
Total (Prairie Provinces)	43 057	61 253	+42	34 015	45 396	+33	29 554	44 550	+51
British Columbia	34 152	37 727	+10	31 530	34 910	+11	22 365	21 877	−2
Total Canada	231 456	273 203	+18	216 964	236 249	+9	176 599	204 286	+16

Source: Statistics Canada.

engineering construction projects are being performed. The normal market area of a given cement-producing plant depends on the amount of transportation cost that the selling price can absorb. A potential large volume of sales could warrant a secondary distribution terminal; water transportation to a distribution system could extend a plant's market area even farther. Because raw materials for cement manufacture are generally widespread, most countries can supply their own cement requirements if the market volume warrants a plant. Few countries rely entirely on imports for their cement needs. However, some countries rely heavily on export markets for their cement production in order to operate facilities economically.

Specialty cements such as white cement are transported greater distances than ordinary grey portland cement when the transportation costs do not represent as high a proportion of the landed price and when quantities required are generally much smaller than for portland cement. Cement shortages in countries experiencing a buoyant surge in construction have led to exceptions to the norm and resulted in cement being shipped unusual distances.

Cement from plants in the United States and Canada is traded between the two countries where competition and tariffs permit. The 1973 situation in which record amounts of both cement and clinker were exported to the United States market was an anomaly created by the combined effects of a cement shortage in parts of the United States and an extremely buoyant construction industry. A sliding economy has had an immediate and strong effect on United States construction activity since that time and the cement industry in turn was forced to adjust to reduced demand for its product. Exports of portland cement from Canada to the United States were reduced by 10 per cent in 1974, another 14 per cent in 1975 and 6 per cent in 1976, as the predicted recovery in construction activity did not materialize. A depressed cement market in Canada followed that in the United States, with a most pronounced drop in production and shipments noted in early-1975. Recovery, however, seemed more rapid in Canada and a trend to greater cement usage began in late-1975.

Although cement is used mainly in the construction industry, significant amounts are used also in the mining industry to consolidate backfill. Amounts so used grew from about 5000 tons in 1960 to a reported 231 000 tons in 1970, the increase being related to the mechanization of backfilling techniques and to research conducted with support from the National Research Council's Industrial Research Assistance Program.

A typical feature of the cement-manufacturing industry is its diversification and vertical integration into related construction materials industries. Many cement companies also supply ready-mix concrete, stone, aggregates and preformed concrete products such as slabs, bricks, and prestressed concrete units.

Outlook

Construction expenditures in 1977 will be between $35 and $36 billion which will result in a real growth of about 3 per cent. The labour scene could become disturbing as a number of contracts, which were in force prior to the advent of the Anti-Inflation Board (AIB), will be up for renewal during 1977. Housing needs, along with favourable mortgage rates, will maintain the buoyancy of the residential building sector, and engineering construction relating to energy projects will result in greater expenditures in that field. Construction in Canada will continue to show an annual increase in value and cement producers will have to compete with producers of all other building materials to obtain a share of the construction dollar. Not only is practical research in the use of cement-concrete needed, but effective advertising and public relations must be used to encourage acceptance of modular construction at a time when reasonably priced, attractive and convenient housing units are in short supply. In general, modest gains are expected in the near-term, with activity across the country expected to range from promising to cautious.

The availability of other construction materials has played a major role in determining the amount of cement required for construction. Projects have been delayed because of shortages of steel, rebar, gypsum products and other items, and shortages of certain materials could create problems again. Of particular concern in this regard will be sources of energy. The cement industry has long recognized the importance of fuel conservation, if for no other reason than that fuel costs have represented a major portion of its total operating costs. A voluntary commitment by the Canadian industry to reduce unit fuel consumption by 9 to 12 per cent by 1980 (with 1974 as the base year) has been undertaken. The already-established trend to dry processing and the use of preheaters will continue for new plants, while the rehabilitation of older plants will continue to benefit from new technology. Rebuilding programs are costly, especially when they must be accomplished with no loss in production. The obvious incentives of cost savings and greater profits must be attractive enough to warrant the expense and effort. The expense of adapting older facilities to meet newly imposed environmental-control regulations can contribute to a decision in favour of a new plant — such decisions have forced a number of plant closures in the United States. Continued diversification and vertical integration by cement producers will eventually result in the write-off of some comparatively inefficient production capacity as the emphasis on a cement-concrete industry increases. Work stoppages have seriously delayed many construction projects. In general, labour relations in the construction industry have shown improvement, with a mature and rational approach to labour-management problems which, hope-

Table 10. Canada, production of concrete products

	1975	1976^p
Concrete bricks (number)	130 247 689	143 834 994
Concrete blocks (except chimney block)		
Gravel (number)	226 081 174	176 223 844
Other (number)	39 305 525	36 889 256
Concrete drain pipe, sewer pipe, water pipe and culvert tile (tonnes)	1 564 306	1 316 109
Other precast products (tonnes)	145 776	150 094
Concrete, ready-mix (cubic metres)	12 656 779	13 192 562

Source: Statistics Canada.
^{p}Preliminary.

Table 11. World production of cement, 1965 and 1975

	1965	1975^p	Increase
	(000 tonnes)		(%)
U.S.S.R.	72 387	122 000	69
Japan	32 689	65 519	100
United States	66 318	63 251	−5
Italy	20 695	34 235	65
West Germany	34 133	33 516	−2
People's Republic of China	11 000^e	30 000^e	173
France	22 365	29 249	31
Spain	9 692	23 976	147
Poland	9 573	18 552	94
United Kingdom	16 961	16 896	−1
Brazil	5 621	16 700^e	197
India	10 578	16 234	53
Romania	5 406	12 000^e	122
Mexico	4 304	11 612	170
Turkey	3 328	10 740	223
East Germany	6 087	10 656	75
Republic of Korea	1 614	10 129	528
Canada	7 645	9 965	30
Other Countries	93 426	160 309	72
Total	433 822	695 539	

Sources: Statistics Canada; U.S. Bureau of Mines *Minerals Yearbook, 1968* for 1965, and U.S. Bureau of Mines *Mineral Trade Notes, Vol. 74, No. 1-2,* January-February 1977.
^{p}Preliminary; ^{e}Estimated.

fully, will continue and thereby do much to reduce the cyclical aspects of the industry. The shortage of skilled labour could reach problem proportions for the construction industry; if not generally, certainly in some regions, as more and larger projects are undertaken.

The cement industry in Canada is capable of meeting the immediate demands on it and is in a position to expand in anticipation of even greater demand and to take advantage of foreign market openings should they be presented.

Although individual companies continue to conduct research relative to cement production, much experimentation concerning the use of cement and concrete is done through the Portland Cement Association (PCA), an industry-supported, non-profit organization whose purpose is to improve and extend the uses of cement and concrete through scientific research and engineering fieldwork. The Association is active in all parts of Canada and can offer detailed information on concrete use, design and construction from its regional offices.

Cement manufacture is energy-intensive. It is obvious that research should be concentrated in this area, and specifically within the pyroprocessing sector, where over 80 per cent of the energy is consumed. Raw material grinding and finish grinding are also being studied to determine optimum particle size for energy consumed.

In terms of the energy content in concrete structures and the energy requirements to service and maintain concrete structures they are not so energy-intensive as the more than 5 million Btu's per tonne of cement would at first indicate.

Table 12. Apparent consumption of cement by the leading producers, 1975

	Production[p]	Apparent Consumption	kg/ capita
	(000 tonnes)		
U.S.S.R.	122 000	119 489	470
Japan	65 519	63 222	547
United States	63 251	60 080	283
Italy	34 235	33 948	608
West Germany	33 516	31 766	511
People's Republic of China	30 000[e]	28 100	32
France	29 249	28 634	543
Spain	23 976	20 752	582
Poland	18 552	19 340	568
United Kingdom	16 896	16 853	301
Brazil	16 700[e]	16 653	158
India	16 234	16 059	27
Romania	12 000[e]	9 520	448
Mexico	11 612	11 522	192
Turkey	10 740	9 977	255
East Germany	10 656	10 373	615
Republic of Korea	10 129	8 435	248
Canada	9 965	9 165	401
Other Countries	160 309		
Total	695 539		

Sources: Statistics Canada, U.S. Bureau of Mines, *Mineral Trade Notes, Vol. 74, No. 12,* January-February 1977. *Cembureau Statistical Review, 1974/1975.*
[p]Preliminary; [e]Estimated.

World review

Because of the direct relationship between cement, concrete, and construction, the consumption of cement can be monitored as an indication of a country's rate of development.

World production in 1976 was estimated to be 767 million tonnes. Inflationary pressures have curtailed construction activity in many countries and cement consumption has dropped accordingly. With the rate of increase in consumption having decreased from that estimated a few years ago, and from that rate on which capacity increases were authorized, excess capacity currently exists in some developed countries. Developing countries, particularly oil-producing countries, continue to show increasing demand for cement and cement-manufacturing facilities. Involvement, through provision of design and technical expertise, of cement and construction corporations from developed coun-

Table 13. Apparent consumption of cement, 1975 — leading consumers

	Consumption	Consumption per capita
	(000 tonnes)	(kg)
U.S.S.R.	119 489	470
Japan	63 222	547
United States	60 080	283
Italy	33 948	608
West Germany	31 766	511
France	28 634	543
People's Republic of China	28 100	32
Spain	20 752	582
Poland	19 340	568
United Kingdom	16 853	301
Brazil	16 653	158
India	16 059	27
Mexico	11 522	192
East Germany	10 373	615
Turkey	9 977	255
Romania	9 520	448
Canada	9 165	401

Source: *Cembureau Statistical Review,* 1974/1975.

tries in the building of cement production facilities in these countries has become quite common.

Conservation of energy and raw materials within the cement industry is of world-wide concern and provides a theme around which major developments in the industry have taken place. Of particular note is the emphasis on blended cements and the utilization of slag, ash and other byproducts. Even greater additions to production capacities than those witnessed during the past few years will be needed to meet demand in many developing countries.

The following paragraphs, based on data collected and reported in *Rock Products* and/or *Pit and Quarry* magazines, are indicative of trends in the regions noted, but in no way represent a total coverage of world activity:

North America. During 1976 about 3.0 million tonnes of new cement production capacity went into operation in the United States while plant shutdowns reduced capacity by over 1.6 million tonnes. The new capacity was in the form of two essentially new plants which replaced existing plants at the same locations — Citadel Cement Corporation, which doubled the capacity of its Roanoke, Virginia plant to just over 1 million tonnes a year; and Universal Atlas Cement Division, which completed a 540 000-tonne-a-year plant at its Leeds, Alabama site. Four major expansions were recorded during 1976: Lehigh Portland Cement Company spent $14 million to increase the capacity of its Mitchell, Indiana plant by 340 000 tonnes a year; Martin Marietta Corporation added about 130 000 tonnes a year to its Roberta, Alabama plant, mainly by a new grinding mill, at a cost of $19 million; National Cement Company Inc., now owned by Société des Ciment Vicat of Grenoble, France, added a four-stage suspension pre-heater to a shortened, existing kiln, increasing capacity by about 580 000 tonnes a year at its Ragland, Alabama plant; and Portland Cement Company of Utah completed a $6 million project which increased the capacity of its Salt Lake City plant by 135 000 tonnes a year.

Table 14. Cement, world production

Country	1975[p]	1976[e]
	(000 tonnes)	
U.S.S.R.	122 000	127 000
United States (incl. Puerto Rico)	63 251	68 000
Japan	65 519	65 000
Italy	34 235	33 000
West Germany	33 516	32 000
People's Republic of China	30 000[e]	32 000
France	29 249	30 000
Spain	23 976	24 000
United Kingdom	16 896	15 000
Canada (shipments)	9 965	9 850
Other Free Countries	192 319	209 150
Other Communist Countries	74 613	51 000
Totals	695 539	696 000

Sources: U.S. Bureau of Mines, Commodity Data Summaries, January 1977; U.S. Bureau of Mines Mineral Trade Notes, Vol. 74, No. 1-2, January-February 1977. For Canada, Statistics Canada.
[e]Estimated; [p]Preliminary.

Programs scheduled for completion during the next three years will provide close to 1.5 million tonnes a year of new capacity and over 4 million tonnes a year from expansions at existing plants. The major additions are as follows:

The Cantex Corporation has contracted with the Fuller Company for a new $32 million, 453 000-tonne, dry-process plant at Austin, Texas. The preheater system is designed for the later addition of a coal-fired flash calciner, illustrating what could be two trends with future new installations — the use of flash calciners and the use of coal. Citadel Cement Corporation, a joint venture of Lone Star Industries Inc. and Canada Cement Lafarge Ltd., has nearly completed its new 680 000 tonne-a-year plant at Demopolis, Alabama at a cost of $50 million.

Lone Star Lafarge Co., a joint venture of Lone Star Industries Inc. and Lafarge Fondu International of Paris, France, plans a $10 million plant at Chesapeake, Virginia for the manufacture of calcium aluminate cements.

Marquette Cement Manufacturing Company, a subsidiary of Gulf & Western Industries, Inc. intends to construct a new 900 000 tonne-a-year plant to replace the 250 000-tonne plant at Cape Girardeau, Missouri.

Coplay Cement Manufacturing Co. will spend $50 million on a modernization program at its Nazarith, Pennsylvania plant which will increase capacity by 900 000 tonnes a year. Lehigh Portland Cement Company will add 450 000 tonnes a year to the capacity of its Mason City, Iowa plant with a new kiln and a four-stage suspension preheater with a precalciner. Both the kiln and precalciner are to be coal-fired.

Louisville Cement Co. will install a 600 000 tonne-a-year, four-stage suspension preheater at its Speed, Indiana plant.

Central America and the Caribbean. In 1976 capacity increases were limited to a new plant in the Dominican Republic by Cementos Nacionales and an expansion program (400 000 tonnes a year) by Maritires de Artemisa in Cuba.

A new plant planned for Barbados will produce up to 225 000 tonnes a year of clinker, 40 per cent of which will be shipped to Guyana for finish grinding. In Panama, Empresa Estatal de Cemento Bayano has contracted for a new 300 000-tonne-a-year plant to be built north of Panama City at Calzada Larga.

Table 15. Canada, value of construction by province, 1975-77

	1975[1]			1976[2]			1977[3]		
	Building Construction	Engineering Construction	Total	Building Construction	Engineering Construction	Total	Building Construction	Engineering Construction	Total
	(thousands of dollars)								
Newfoundland	343 153	273 930	617 083	377 093	335 418	712 511	431 575	318 626	750 201
Nova Scotia	465 270	298 898	764 168	499 195	352 896	852 091	502 375	446 791	949 166
New Brunswick	409 749	419 223	828 972	449 044	336 650	785 694	460 702	351 492	812 194
Prince Edward Island	69 782	37 753	107 535	61 409	33 861	95 270	60 585	35 356	95 941
Quebec	4 472 319	2 638 661	7 110 980	4 769 251	2 700 204	7 469 455	4 564 800	3 623 791	8 188 591
Ontario	5 757 247	3 232 152	8 989 399	6 331 767	3 499 439	9 831 206	6 467 874	3 687 530	10 155 404
Manitoba	562 689	449 954	1 012 643	722 562	509 962	1 232 524	779 899	531 664	1 311 563
Saskatchewan	682 316	448 237	1 130 553	850 363	531 042	1 381 405	916 035	617 209	1 533 244
Alberta	1 651 216	2 269 646	3 920 862	2 434 672	2 618 285	5 052 957	2 695 252	3 061 641	5 756 893
British Columbia, Yukon Territory and Northwest Territories	2 195 674	1 698 475	3 894 149	2 538 754	1 821 311	4 360 065	2 584 597	2 211 531	4 796 128
Canada	16 609 415	11 766 929	28 376 344	19 034 110	12 739 068	31 773 178	19 463 694	14 885 631	34 349 325

Source: Statistics Canada. [1]Actual; [2]Preliminary; [3]Forecast.

Plant expansions are scheduled as follows: In El Salvador, Cemento de El Salvador S.A. has contracted for a dry-process, suspension preheater system that will increase the capacity of its plant at El Ronco, Metapan by 300 000 tonnes a year. Caribbean Cement Co. Ltd. is to install 400 000 tonnes a year of additional capacity at its Kingston plant. In Mexico five expansion programs are under way: Cementos Mexicanos S.A. at Monterrey (400 000 tonnes a year), Cementos Maya S.A. at Merida in Yucatan (375 000 tonnes a year), Cementos Guadalajara S.A. at Ensenada in Baja California (400 000 tonnes a year), Cementos Hidalgo, S.C.L. at Hidalgo, an unspecified amount; and La Cruz Azul at Hidalgo, also an unspecified amount.

South America. In 1976 four new plants began production of cement in Brazil, and one in Columbia. Itabira Agro-Industrial S.A. put its new plant at Cappao Bonito on stream with a capacity of about 300 000 tonnes a year. Cemento Nacional de Minas S.A. began production from a 780 000-tonne plant at Pedro Leopoldo, while at Sao Paulo, Cemento Santo Rita S.A. started up a 600 000-tonne-a-year plant. A new plant of undisclosed capacity was put on stream in Rio de Janeiro by Cemento Tupi. In Colombia a new plant of about 300 000 tonnes a year operated by Cementos del Valle S.A. went on stream at Calle. Two new plants are planned for Colombia — at Cartegena, Compania Colombiana de Clinker S.A. is building a two-kiln wet process plant of 600 000 tonnes capacity, and at Barranguilla, Cementos del Carbide S.A. is installing a wet process system of about 300 000 tonnes a year.

In Equador, La Cemento Nacional C.E.M. plans a 450 000-tonne plant at Guayaquil for 1977, while Surveyer, Nenniger & Chênevert, Inc. of Montreal will supply design, engineering and project management for a $24 million plant with a capacity of 345 000 tonnes a year.

A dry-process plant and marine distribution facilities are scheduled for 1978 operation by Cementos Caribe C.A. at Puerto Cumarebo near Coro, Venezuela.

Plant expansions are scheduled as follows:

In Bolivia, Sociedad Boliviana de Cementos S.A. will increase capacity of its Viacha plant near LaPaz by 150 000 tonnes a year. In Peru, Cementos Norte Pacasmayo will install a preheater and flash calciner at the Pacasmayo plant to add about 540 000 tonnes a year of capacity by 1977, while Cementos Lima S.A. is working towards a 900 000-tonne expansion of its Atacongo plant near Lima.

Europe. Only two completely new plants are planned in Europe, according to available information. In France, Ciment Français (Bussac) has awarded a contract for the construction of a preheater kiln system rated at approximately 540 000 tonnes a year; and in Greece, M.A. Karageorgis S.A. has contracted for a 1-million-tonne-a-year plant at Messinia.

Nine plant extensions, two of which occurred in 1976, are noted in a total of seven countries. Ciments du Sud-Ouest of France will convert one kiln at its Lexos plant from wet to dry and will include in the conversion a Japanese-developed precalcining system. An additional 275 000 tonnes a year of capacity will result. Cement Ltd., Dublin, Ireland is expanding its Platin plant by over 800 000 tonnes a year with the addition of a new mill, new kiln and twin four-stage suspension preheaters. A 1.4 million-tonne addition will be made to the Slite plant of Cementa A.B. in Sweden by 1979. In Yugoslavia, Dalmacija Cement will increase capacity of its Paitizan plant by nearly a million tonnes a year while Fabrika Cementa Novi Popuvac in Popowas is planning a 600 000-tonne increase.

Asia. At least 19 new plants (four in 1976) are planned for Asian countries, increasing capacity by over 12 million tonnes a year during the next three years. Projected expansions total about 8 million tonnes a year. The new plants in 1976 were as follows: a two-kiln plant of about 1 million tonnes for Aria Cement Corp. in Iran; two plants in Taiwan, one at 600 000 tonnes a year for Tang Eng. Iran Works and one of 720 000 tonnes a year at Taipei for China Rebar Co. Ltd.; and a 210 000-tonne plant in the United Arab Emirates.

Some of the new plants under construction or in the planning stages, together with new capacity in the form of expanded facilities are as follows: in India a new, two-kiln plant of 720 000 tonnes a year capacity is under construction for Century Cement near Maihar and a 360 000-tonne expansion of a plant at Nimbahera operated by J.K. Cement Works is planned. Two new plants, each 600 000 tonnes, are under construction in Indonesia, one in Western Sumatra at Indarung, one at Cilacap in Central Java. Two major expansions are underway, one at Cibinong and one for nearly 1 million mtpy at Gresik. In Iran two new plants totalling over 1.5 million tonnes a year are being built, one for Fars & Khuzestaw Cement Co. at Behbahan, one at Abe-Ali for Shemal Cement Co. A 600 000-tonne-a-year expansion of the Rey Cement Co. plant at Rey, and a similar expansion at Soufian Cement Co.'s Tabriz plant, are underway. A four-kiln cement plant with a capacity of over 2 million tonnes a year is being constructed for the government of Iraq. Capacity increases in the Japanese cement industry are limited to a 1.2 million-tonne expansion at Tagawa by Aso Cement Co. One new plant with a capacity of 1 million tonnes a year is planned by Kuan Hsi Cement Corp. for Kaohsiung in the Republic of South Korea, while two expansion projects are under construction, one at Seoul by Tong Yang Cement and one by Ssang Yong Cement Industries Co. Ltd. at Tonghae for over 2 million tonnes a year. In Saudi Arabia each of two Jidda-based cement companies, Arabian Cement Co. and Yambu Cement Co., have contracted for construction of a 1-million-tonne-a-year plant near Jidda, while Saudi Cement Co. will have a new plant of similar capacity

Table 16. Value of construction in Canada, 1975-77

	1975[1]	1976[2]	1977[3]	Change 1976-77
	(millions of dollars)			(%)
Building construction				
Residential	8 689	11 578	11 863	2.5
Industrial	1 510	1 455	1 502	3.2
Commercial	3 732	3 328	3 257	−2.1
Institutional	1 561	1 511	1 565	3.6
Other building	1 117	1 162	1 277	9.9
Total	16 609	19 034	19 464	2.3
Engineering construction				
Marine	181	170	222	30.6
Highways, aerodromes	2 382	2 614	2 736	4.7
Waterworks, sewage systems	1 241	1 316	1 509	14.7
Dams, irrigation	138	113	128	13.3
Electric power	2 825	3 098	3 861	24.6
Railway, telephones	1 099	1 192	1 269	6.5
Gas and oil facilities	1 850	2 334	2 943	26.1
Other engineering	2 051	1 902	2 217	16.6
Total	11 767	12 739	14 885	16.9
Total construction	28 376	31 773	34 349	8.1

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

built in eastern Saudi Arabia. In Turkey a 750 000-tonne plant will be built at Instanbul for Canakkale Cemento Sanayii, A.S. and a 500 000-tonne-a-year unit will be constructed at Yozgat in Central Anatolia. Two expansions are under way, one for 520 000 tonnes a year, one for 240 000 tonnes a year.

Africa. There are many more new plants scheduled for African countries than plant expansions. Only one new plant was reported on stream in 1976, a 400 000-tonne plant for Société des Ciments de Marrakech S.A. at Marrakech, Morocco. Other capacity increases under way or planned include the following: in Algeria, five new plants have been contracted for by Société National Matériaux de Construction: a 1.1 million-tonne-a-year, dry-process plant at Zahana scheduled for 1977; a 500 000-tonne plant at Saida for 1978; a 1-million-tonne plant for 1979 in El Asanm; a 1-million-tonne plant at Beni-Saf and a 1-million-tonne plant at Constantine. In the Arab Republic of Egypt a 750 000 tonne-a-year expansion project by Ciment Portland Tourah is under way. Contracts have been awarded for two plants in Gabon to the Société des Ciments du Gabon; one for a 300 000-tonne unit at N'toum and one at Franceville for 100 000 tonnes a year. In Libya two new plants are being constructed for the Libyan Arab Republic through its General National Organization for Industrialization. One plant, scheduled for 1978, will be located at Hawari and have a capacity of about 1 million tonnes a year, the second will be located near the coastal city of Homs, will have a capacity of 900 000 tonnes a year and be completed in 1979. In Morocco, besides the new plant on stream in 1976, two others are planned; one of unrevealed capacity for 1978 at Rabat for Asment de Temara, and a 1-million-tonne-a-year plant at Oujda for Cementerie Maghrebin. In Nigeria, Ashaka Cement Co. has scheduled a two-kiln plant of 600 000-tonne capacity for operation in 1977 at Ashaka; while in Tanzania, Tanzania Saruji Corp. has contracted for a 500 000-tonne-a-year plant at Tanga.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(c)	(c)	(c)	(c)
29000-1	Portland and other hydraulic cement, nop; cement clinker per 100 lb*	free	free	6	free
29005-1	White, nonstaining portland cement, per 100 lb	4	4	8	2⅔

United States

Item No.		(¢ per 100 lb incl. weight of container)	(%)
511.11	White nonstaining portland cement	1	
511.14	Other cement and cement clinker	free	
511.21	Hydraulic cement concrete		free
511.25	Other concrete mixed		7.5

Sources: For Canada, the Customs Tariff and Amendments Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), TC Publication 749.

Cesium

J.G. GEORGE

Cesium is a soft, silvery white, ductile metal with a melting point of 28.5°C, a boiling point of 705°C, a density of 1.87 grams per cubic centimetre at 20°C and an atomic weight of 132.91. It is one of the three metals (the others are mercury and gallium) that are liquid at room temperature. Cesium is the fortieth most common element in the earth's crust, about as abundant as germanium. It is the eighth lightest metallic element but, of the five naturally occurring alkali metals, cesium is the most electropositive, has the highest density, highest vapour pressure, lowest boiling point and lowest ionization potential. Because of these properties cesium is used in preference to other alkali metals in such space-age applications as space propulsion and energy conversion.

Cesium emits electrons when exposed to visible light, ultraviolet light or infrared light. It is an efficient scavenger for traces of oxygen in highly evacuated containers. Cesium resembles potassium and rubidium in the metallic state and is similar to them in chemical behaviour, but oxidizes more readily than any of the other alkali metals. Precautions must be taken in handling, transporting and storing cesium metal because in air or water it is very reactive chemically, and when exposed to a combination of the two it reacts violently. The vigour of the reaction of cesium with water is evidenced by the fact that the metal reacts with ice at all temperatures above −116°C, liberating hydrogen. The reaction with cold water is explosive. Cesium is usually packed under argon or in vacuum in Pyrex glass vials or in returnable stainless steel cylinders. The vials of cesium are wrapped in aluminum foil and packed with expanded vermiculite in metal cans for protection against shock and fire. Cesium compounds are not as dangerous as the metal, but they must be handled carefully and shipped in closed containers. Most cesium salts are somewhat hygroscopic and should be stored in properly sealed containers and kept in a dry location. Their toxicity is usually low, but cesium fluoride is toxic and should be handled with care.

Occurrences and recovery

Of the naturally occurring alkali metals, cesium is the least abundant. It is widely distributed in the earth's crust, usually in low concentrations. It occurs in certain granites and granitic pegmatites, with granites having been estimated to contain an average of about one part per million of cesium. Cesium also occurs in brines and saline deposits, but little information is available on such cesium resources. Greater concentrations of cesium are found in lepidolite, carnallite, beryl, leucite, spodumene, petalite and related minerals. Although commercial quantities of cesium have been obtained from both lepidolite and carnallite, the most important economic source of the metal is the rare mineral pollucite. Pollucite is usually found in complex, generally well-zoned, pegmatite dykes that are rich in lithium minerals, especially lepidolite.

Pollucite, a mineral resembling quartz in lustre and transparency, is a hydrated silicate of aluminum and cesium ($H_2O \cdot 2Cs_2O \cdot 2Al_2O_3 \cdot 9SiO_2$) with the theoretically pure mineral containing 45 per cent cesium oxide (Cs_2O). Naturally-occurring pollucite usually contains from 6 to 32 per cent Cs_2O. The higher-grade variety of pollucite has a specific gravity of 2.9 and a hardness of 6.5 on Mohs' scale. It is colourless to white, or greyish or pinkish white.

The largest known reserves of pullucite are: about 45 000 tonnes* in the Karibib area in South-West Africa, some 135 000 tonnes in the Bikita district of Rhodesia, and 372 000 tonnes at the mine of Tantalum Mining Corporation of Canada Limited (Tanco) at Bernic Lake in southeastern Manitoba, Canada, about 110 miles northeast of Winnipeg. A second Canadian occurrence is at the Valor property in Lacorne Township, northwestern Quebec, formerly owned by Massval Mines Limited. Mocambique also has pollucite deposits, but reserves and grade are not known. Other occurrences are found in the island of Elba and at Veratrask, Sweden. Occurrences in the United States are in Oxford County, Maine, and in the Black Hills near Custer, South Dakota. In recent years there has

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

been no commercial production of cesium-bearing minerals in the United States, and the likelihood of any future domestic production of such minerals remains poor. Pollucite imported from Canada is, and will for some time continue to be, the main source of the United States production of cesium and its compounds. In fact, the world itself is currently dependent on the known deposits of pollucite in Canada and southern Africa for its cesium requirements.

The only known Canadian cesium-bearing deposit of economic importance is the one at Bernic Lake, Manitoba. Tanco, which operates the property, is owned 50.1 per cent by International Chemalloy Corporation; 24.9 per cent by Kawecki Berylco Industries, Inc.; with the remaining 25 per cent interest being held by the Manitoba Development Corporation (MDC), the investment agency of the Manitoba Government. The pollucite ore zones are separate from the company's tantalum and lithium orebodies (although these do contain low cesium values) which are contained in the same deposit. The pollucite unit consists of three gently dipping, sheet-like bodies, the largest of which ranges up to 14 metres in thickness and lies in the southeast quadrant of the pegmatite. As of December 31, 1976 the company's cesium ore reserves consisted of 270 000 tonnes of pollucite averaging almost 23.9 per cent Cs_2O in the main zone, 47 000 tonnes averaging almost 23.9 per cent Cs_2O in one westerly zone and 55 000 tonnes of somewhat lower grade in the second westerly zone. These reserves are before dilution allowance or pillar allowance. The main zone is open to the south and could be extended by further drilling. In addition, there are large areas of the pegmatite body containing quantities of pollucite averaging 500 to 1500 grams of Cs_2O a tonne which have not yet been assessed for ore reserves. Also, deeper drilling below the main pegmatite body has indicated a second sill approximately 30 metres below the main body, which contains pollucite, tantalite, and spodumene mineralization.

At the Valor property in northwestern Quebec, masses of pollucite up to about 1.5 metres in maximum exposed dimension are scattered through part of a lenticular core zone of a complex dyke. The zone consists chiefly of quartz, cleavelandite and spodumene, with irregular masses and disseminations of lepidolite.

Ores naturally rich in pollucite have been upgraded experimentally with some success, but satisfactory methods to concentrate pollucite economically from low-grade ores have not yet been developed. The United States Bureau of Mines has, however, developed experimentally a froth flotation process for concentrating pollucite ore. When applied to a low-grade cesium ore from the state of Maine grading about 8 per cent Cs_2O, the ore was upgraded to over 21 per cent Cs_2O with a cesium recovery of almost 87 per cent. Commercial concentrates and direct shipping ore usually grade in excess of 20 per cent Cs_2O. At present all cesium raw materials requirements of the United States are met from imports.

Thermochemical and hydrometallurgical methods are used for the production of cesium salts and compounds from pollucite ore. Cesium metal can be produced by direct thermochemical reduction of pollucite ore under vacuum or in an atmosphere of an inert gas (argon or helium), or by thermochemical reduction of a cesium compound under vacuum. Frequently-used methods of producing elemental cesium are the heating of cesium carbonate with magnesium at about 675°C under hydrogen, or the heating of cesium chloride with calcium at the same temperature under vacuum. In both cases the metal is condensed from the vapour state in the absence of air, frequently under an inert oil to protect it from reaction with the atmosphere. Cesium metal has also been produced on a laboratory scale by electrolysis but this method of recovery has not yet proved economically feasible.

Production and consumption

Little statistical data is available on the production and consumption of pollucite or cesium metal and compounds. Annual world mine production of pollucite ore was estimated at only 20 tonnes as recently as 1968. Since then an increasing demand has resulted in a significantly greater output of pollucite. From late 1969, when Tanco's Bernic Lake mine began operations, until the end of 1975, shipments of pollucite ore totalled about 1 400 tonnes with an average Cs_2O content of almost 27 per cent. Of these total pollucite shipments, almost 86 per cent were exported to Russia and approximately 8 per cent went to the United States; with the remainder going to the United Kingdom, West Germany and Japan. All of the company's shipments of pollucite made to the end of 1975 have been in the form of crushed ore. In 1976 the Bernic Lake mine did not make any shipments of pollucite ore and late in that year the Canadian government placed cesium in all forms, including ores, concentrates, chemical compounds, and cesium metal and alloys containing cesium, on the Export Control List established under the regulations of the Export and Import Permits Act. This legislation in effect banned shipments of cesium in all the above-mentioned forms to all communist countries, including the U.S.S.R., named in the Area Control List.

Until 1968 world consumption of cesium metal and compounds was probably less than ten tonnes a year. In the past few years there has been a major increase in consumption mainly because of the increasing quantities of cesium compounds used in experimental magnetohydrodynamic (MHD) electrical power generators. The U.S.S.R. is probably the largest consumer of cesium in the world. It has imported over 1 200 tonnes of pollucite from Canada between late 1969 and the end of 1975, which suggests an annual consumption in the range of about 52 000 kilograms of cesium metal equivalent, unless some of these imports were put into stockpile. The U.S.S.R. has for several years been doing extensive research in MHD generation of electricity and it is reported that a cesium compound has been used in the process.

Uses

At present there are no large-scale commercial uses for cesium. The end-use pattern has remained unchanged in recent years with the largest portion of consumption occurring in the field of research and development. Most of the metal and its compounds are currently consumed in the developmental research of thermionic power conversion units, ion propulsion and MHD electrical power generators. In MHD pilot plants, which make use of cesium's ionization potential, a fuel (coal, oil or gas) is burned. The hot gas is seeded with an easily ionized element such as cesium or potassium compound, or mixed cesium-potassium compound, to increase its conductivity. The ionized gas (plasma) is accelerated through a chamber surrounded by a strong magnetic field, resulting in the generation of electricity which is drawn off through electrodes placed in the channel. The amount of power generated depends on the degree of ionization, the velocity of the plasma, and the magnetic field strength. Significant increases in efficiency and cheaper power with reduced pollution (cesium compounds when used as the "seed" are said to scrub out the harmful sulphur oxides produced by the burning coal or char) can be expected from MHD generators. Cesium salts as well as the metal are possible additives for MHD applications which are still in the research and development phase. While alternative materials, such as rubidium, potassium and sodium, may be used in the process, present knowledge is that cesium compounds appear to be the most efficient.

Late in 1974 it was reported that $150 million to $200 million had been spent worldwide on MHD research in the previous 15 years, with about 75 per cent of that amount being spent in the U.S.S.R. Although the United States has spent much less money than the U.S.S.R. on MHD research, it is believed that the current energy crisis may revive support for greater research efforts in this field. MHD can be powered with any fossil fuel, but the greatest potential contribution in solving today's energy crisis is that this new power-generating technique permits the use of abundantly available coal supplies and bypasses the scarcer oil and natural gas resources.

In thermionic converters the heat from nuclear reaction radiates to a surrounding metal (cathode) which emits large masses of electrons. The electrons travel through a space filled with a gas such as cesium vapour to an anode, which then has a potential with respect to the cathode, and electricity can flow through a circuit joining the anode and cathode. The most important factor limiting the efficiency of thermionic generators is the "space charge" effect. It is caused by the mutual repulsion of electrons wherein electrons in the space between the electrodes repel those emerging from the cathode and return them to the cathode. Ionized cesium gas is used to electrically neutralize the space charge. Nuclear heating is used in thermionic converters as it can serve as the source for the high temperature (1,900°C) required.

In spacecraft, cesium is used in the ion-propelled engines. Vaporized cesium is ionized while passing through a heated porous tungsten disc. The cesium ions become positively charged and an electric field accelerates the positive ions to a velocity of some 483 000 kilometres per hour. The high-velocity ions are neutralized by the injection of electrons and then exhausted through a nozzle to develop thrust. Since ion propulsion is essentially a low-thrust system, one of its potential uses lies either in the maintenance of orbiting space vehicles in their orbits, or in the movement of such vehicles from one orbit to another. An ion engine could be used to move a vehicle from earth orbit to Mars orbit, for example, but could not be used for takeoff from, or for landing on, either planet.

Other commercial applications for cesium include its use in photomultiplier tubes, vacuum tubes, scintillation counters, magnetometers, infrared lamps, pharmaceuticals and as reagents in microanalysis. Another commercial outlet is in photoelectric cells, developed in the early 1930s, in which the photoemissive properties of cesium are utilized. In photoelectric cells light energy, falling on the cesium cathode, causes electrons to be emitted. Light-sensitive cathodes of cesium on a conducting base, such as silver, may be constructed for photocell use, and many alloys of cesium are also photoelectric. The compound $SbCs_3$ has significantly high photoelectric sensitivity. An alloy of cesium and silver is used in the emitron or "electric eye" used in television. Cesium is used as an absorbent to remove impurities at carbon dioxide purification plants and acts as a catalyst in various hydrogeneration and polymerization processes. The metal may also act as a scavenger of gases and other impurities in chemical processing and in both ferrous and nonferrous metallurgy.

In biological research, concentrated cesium chloride solutions are used for density gradient ultracentrifuge separation of DNA, viruses and other large molecules. This could be an important use for cesium and may become one of its largest end-uses, apart from research into MHD power generation. Rubidium salts are sometimes used instead of, or in conjunction with, cesium chloride for ultracentrifuge gradient density separations. Cesium bromide is used in the manufacture of optical crystals. Cesium fluoride finds application as a fluoridating agent in organic syntheses, and cesium hydroxide with rubidium hydroxide can be used in place of lithium hydroxide in alkaline storage batteries for operation at temperatures as low as -50°C. Cesium phosphate is used in the form of mixed crystals, with rubidium and/or ammonium salts, for piezoelectric purposes. Substitutes for cesium in some of its applications are potassium, magnesium oxide, and rubidium which have properties similar to those of cesium or its compounds.

Outlook

So far, the market for cesium metal and compounds has been quite limited, as their high cost and scarcity, as well as the extreme reactivity of cesium metal, restrict their uses to applications where their unique properties are important. The relatively high cost of cesium metal and its compounds also encourages the substitution of other materials wherever possible. The greater availability of substitute materials such as potassium, magnesium oxide and rubidium, with properties similar to those of cesium, is also a factor limiting growth in consumption of cesium and its compounds.

Although accurate data are not available on world production and consumption of cesium and its compounds, currently known world reserves of pollucite ores are thought to be more than adequate to provide for expected world requirements of cesium and its compounds in the foreseeable future. Demand for cesium is expected to increase over the next several years but requirements for research and development purposes could cause significant fluctuations in demand from year to year. Because of existing fuel shortages and increasing world demand for energy, the greatest potential for sharply increased consumption of cesium on a commercial basis appears to be in a technological breakthrough in the development of a power-generating process using cesium-containing compounds. Another source of increased demand would be created if the United States government decided to stockpile pollucite or further-processed cesium compounds or metal. At present, none of these materials are listed for stockpiling in the United States strategic and supplemental stockpiles.

Grades, specifications and prices

Although cesium metal is produced in 99,99.5, 99.9 and 99.97 per cent purities, the two main grades in which it is usually marketed are: standard, with a minimum cesium content of 99.5 per cent; and high purity, with a minimum cesium content of 99.9 per cent. Non-metallic impurities, particularly oxygen, critically affect the corrosive properties, and hence the utility, of cesium metal. Cesium salts are also available and include: acetate, bromide, carbonate, chloride, chromate, fluoride, hydroxide, iodide, nitrate and sulphate. In 1961 the standard specification for technical-grade cesium salts was raised from 97 to 99 per cent pure. Cesium salts are also available in a high-purity grade of 99.9 per cent minimum purity. Cesium is also available in a series of oxides.

Recent nominal quotations for raw pollucite ore of good grade and quality vary between about 50¢ and 75¢ a pound of contained Cs_2O. Cesium salts sell for about \$25 to \$40 a pound depending on the type of salt, grade and quantity purchased. Cesium metal of 99+ per cent purity has been quoted at \$100 to \$375 a pound, depending on the quantity and grade purchased. Three United States companies that produce cesium chemicals are: Kawecki Berylco Industries, Inc., Kerr-McGee Corporation, and Great Western Inorganics, Inc. (formerly Rocky Mountain Research, Inc.).

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92805-1	Cesium	10%	15%	25%	10%
93819-1	Compounds of cesium	10%	15%	25%	10%

United States

Item No.		Non-communist countries	Communist countries except Yugoslavia
601.66	Pollucite	Free	Free
415.10	Cesium	8.5% ad. val.	25% ad. val.
418.50	Cesium chloride	6.0% ad. val.	25% ad. val.
418.52	Other cesium compounds	5.0% ad. val.	25% ad. val.

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), T.C. Publication 749.

Chromium

D. West

Canada does not have any economically mineable deposits of chromium ore (chromite). After the 1974 closure of Union Carbide Canada Limited's ferrochromium plant, the only products made in Canada containing high percentages of chromium were high temperature alloys and chromium-magnesite refractories. Canadian imports of ferrochromium dropped sharply in 1976, reflecting the downturn in the Canadian specialty steel industry.

The predicted upturn in the chromium industry did not occur in 1976; contrary to expectations, world production of stainless steel dropped during the second half of the year. Chrome ore prices maintained their gains of 1975, while several charge chrome producers cut prices in response to fierce competition in the industry.

The outlook for chromium and ferrochromium depends primarily on world demand for stainless steel, which is expected to pick up in 1977. Increasing popularity of the argon-oxygen decarburization (AOD) process will increase demand for charge chrome, while low-carbon ferrochromium will likely become a specialty item.

Canada

There are two principal areas of chromite mineralization in Canada; the Bird River area in Manitoba and the Eastern Townships in Quebec. The Bird River deposits are a continuous band of chromite mineralization, similar in type to the important chrome deposits in Rhodesia and the Republic of South Africa. However, most of the mineralization is lowgrade, 10 to 20 per cent chromic oxide (Cr_2O_3) and has a low iron-to-chromium ratio. This is undesirable, in that the ores are difficult to beneficiate to a marketable product. The Ontario Research Foundation has developed a process for upgrading the Bird River chromite ore to a marketable product, and partially as a result of this, the Manitoba Department of Mines, Resources and Environmental Management is currently conducting a re-evaluation of the Bird River deposits. Deposits in the Eastern Townships are discontinuous, or podiform, deposits. These deposits were exploited earlier in the century and during the Second World War. While these deposits are generally satisfactory in grade and composition, the tonnages are too small to be considered economical. The large number of claim owners in this area discourages major efforts to determine if there are larger deposits at depth.

Union Carbide Canada Limited, which was Canada's only producer of ferrochromium, closed its Welland, Ontario ferroalloy plant in late 1974. The seven furnaces in the Welland plant were small and outdated, and the cost of installing pollution control equipment made the operation uneconomic. The ferrochromium furnaces were to be replaced by a large ferromanganese furnace, but, since Union Carbide was unable to obtain a long-term contract for electrical power from Ontario Hydro, the ferromanganese furnace was subsequently located at Beauharnois, Quebec.

Canadian consumption of ferrochromium in 1976 was 21 923 tonnes* (gross weight), compared with 41 109 tonnes in 1975. The decrease in consumption reflects the downturn in demand for stainless steel throughout the year. The principal consumers of ferrochromium in Canada are: Atlas Steels Division of Rio Algom Limited, Colt Industries (Canada) Ltd., The Steel Company of Canada, Limited, The Algoma Steel Corporation, Limited and several iron and steel foundries. Atlas Steels, Canada's largest producer of stainless steel, is currently increasing the ingot capacity of its melt shop at Welland from 226 800 tonnes to 290 300 tonnes. This will result in greater ferrochromium consumption. The development of the AOD step will lead to an increased use of high-carbon ferrochromium in the production of stainless steel.

Canadian consumption of chromite ore in 1976 was 30 783 tonnes, compared with 36 783 tonnes in 1975.

At present there is only one important consumer of chromium metal in Canada — Deloro Stellite Division

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*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

of Canadian Oxygen Limited, Belleville, Ontario. However, Inco Limited plans to build a rolling mill at Sudbury, Ontario. The mill capacity will be 20 million pounds of copper-nickel alloy strip a year. Since a number of nickel alloys contain chromium, it is possible that Canadian chromium consumption may increase significantly on completion of the plant in 1977.

Canadian demand for ferrochromium is expected to rise to about 45 000 tonnes a year by 1980, and the bulk of these imports will most likely come from South Africa. Similarly, if the Inco rolling mill does utilize chromium metal powders, the increase in demand will again be satisfied by imports and the likely source will be the United States.

Table 1. Canada, chromium imports, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Imports				
Chromium in ores and concentrates				
Philippines	9 579	827 000	21 641	1 810 000
United States	13 071	1 209 000	10 580	1 598 000
Republic of South Africa	2 783	185 000	3 717	1 452 000
Turkey			2 538	492 000
Other countries[1]	4 230	527,000	1 433	169 000
Total	29 663	2 748 000	39 909	5 521 000
Ferrochromium				
Republic of South Africa	20 174	11 069 000	10 066	6 158 000
United States	4 824	4 565 000	6 864	5 223 000
Brazil	12 980	5 524 000	3 996	1 543 000
Other countries[2]	3 131	4 379 000	997	891 000
Total	41 109	25 537 000	21 923	13 815 000
Chromium sulphates, including basic				
United States	1 291	552 000	1 059	461 000
United Kingdom	219	90 000	267	107 000
Total	1 510	642 000	1 326	568 000
Chromium oxides and hydroxides				
United States	760	942 000	1 106	1 429 000
United Kingdom	37	52 000	76	95 000
Netherlands			50	45 000
Other countries[3]	158	199 000	29	35 000
Total	955	1 193 000	1 261	1 604 000
Chrome dyestuffs				
West Germany	3	31 000	6	47 000
United States	8	30 000	7	33 000
Other countries[4]	15	87 000	9	48 000
Total	26	148 000	22	128 000

Source: Statistics Canada.
[1]Includes Cyprus and Portugese Africa. [2] Includes West Germany, Norway, Sweden and Japan. [3] Includes West Germany, France, Poland, Switzerland, Japan and People's Republic of China. [4] Includes United Kingdom, France, Netherlands, Switzerland, Italy, and Japan.
pPreliminary: — Nil.

Grades of ore

The only commercially important ore of chromium (Cr) is chromite. Chromite ores contain varying amounts of iron (Fe), magnesium (Mg) and aluminum (Al). The theoretical formula of pure chromite is $FeOCr_2O_3$ (68% Cr_2O_3) (32% FeO), however, in nature chromite is a combination of oxides of various elements having the general formula of (FeMg) O $(CrAlFe)_2O_3$. There are three principal grades of ore: metallurgical, refractory and chemical (Table 3).

World developments

World mine production of chromite ore rose in 1976 to an estimated 8.0 million tonnes from 7 930 000 tonnes in 1975. The largest producers of metallurgical-grade chromite are: Rhodesia, the Republic of South Africa, Turkey and the U.S.S.R; the largest producer of refractory-grade chromite is the Philippines, while the Republic of South Africa is the largest producer of chemical-grade chromite.

The problems surrounding the availability of chromite from southern Africa have been aggravated by the closure of the Moçambique ports of Maputo (formerly Lourenco Marques) and Beira to Rhodesian traffic. Beira formerly handled almost all of the Rhodesian chromite exports. While Rhodesia has been able to export chromite through South African ports, volume has been greatly reduced, as these ports are already heavily used. Since 1966 when United Nation sanctions were imposed against Rhodesia, very few details on that country's chromite production have been made available. However, recent estimates place output around 610 000 tonnes per year. The principal producers of chromite include Rhodesia Chrome Mines Ltd., African Chrome Mines Ltd., Union Carbide Rhomet (Pvt) Limited and Rio Tinto (Rhodesia) Ltd. These producers are subsidiaries of companies based in the United Kingdom and the United States. A new ferrochrome smelter costing more that $1 300 000 was scheduled to go on stream in 1975.

The Republic of South Africa has approximately 70 per cent of the world's known reserves of chromite. Total chromite ore production from the Bushveld Igneous Complex rose to 2.3 million tonnes, nearly half of the 5-million-tonne production capacity envisioned for 1980. A large part of this increased production will be used by the growing domestic ferrochromium industry.

In early December the General Mining Union Carbide Tubatise ferrochrome operation at Steelpoort made its first pour, well ahead of schedule. Another ferrochromium plant, a joint venture of Johannesburg Consolidated Investment Company (J.C.I.), Consolidated Metallurgical Industries Ltd. — Showa Denko Kahan Kaisha, should be on stream some time in the latter part of 1977. These two operations will each add 120 000 tonnes per year of ferrochromium capacity, most of which is contracted to the foreign partner of each joint venture. Gold Fields of South Africa Ltd. is carrying out a feasibility study on a third plant which could be operational by 1980. Several other ferrochromium producers are expanding their existing operations. South Africa envisions a ferrochromium production capacity of nearly 1 000 000 tonnes a year by 1980.

While the Republic of South Africa has the capability of producting 5 000 000 tonnes a year of chromite and 1 000 000 tonnes a year of ferrochromium, there are several factors beyond the control of the country that may realistically limit the growth of the domestic chromite and ferrochromium industries. The root of the problem is a long-standing arrangement whereby the Republic of South Africa agrees to route a proportion of its chromite exports through the port of Maputo. With this outlet available there was little reason in the past to develop handling facilities for chromite at ports in the Republic of South Africa. As a result, virtually all chromite and ferrochromium were shipped through the port of Maputo. This dependence on a single port was further emphasized by the fact that chromite must be kept clean, and this restricted the use of other ports because it imposed restrictions on the use of bulk-mineral handling terminals. Now, as a result of the closure of the Rhodesia-Moçambique border, a sizeable portion of the spare rail and port capacity of Maputo has been lost to the handling of goods destined for Rhodesia via the Republic of South Africa. Chromite exports from South African ports are already at a maximum. In 1974 the port of Maputo proved unable to handle all the tonnage available to it. Since taking over administration of the rail and port facilities in 1974, the Republic of South Africa has directed some funds to Maputo for the improvement of port bulk-mineral-handling facilities. This situation gives rise to three questions that may restrict growth in the Republic of South Africa.

1. Is there the physical capacity to handle a doubling of chromium product exports by 1980?
2. Will consumers be willing to increase their dependence on the Republic of South Africa, given the current political situation, if other sources of chromite are available?
3. Will consumers be willing to increase their dependency on the Republic of South Africa for ferrochromium, again given the current political situation? If so, there would not be sufficient plant capacity, outside the Republic of South Africa, for the conversion of chromite to ferrochromium to meet the requirements of the major consuming nations. If a long-term disruption of ferrochromium supplies from the Republic of South Africa occurred, the difficulties would be increased by the need to construct ferrochromium plants, on top of the need to find other sources of chromium. Indeed, Japan has

recently expressed reluctance to become more dependent on chromite from the Republic of South Africa because of delivery problems and, further, the Japanese ferroalloy industry has expressed concern over increased dependence on imports of ferrochromium from the Republic of South Africa.

Table 2. Canada, chromium trade and consumption, 1965, 1970, 1974-76

	Imports		Consumption[2]	
	Chromite[1]	Ferrochromium[2]	Chromite	Ferrochromium
	(tonnes)			
1965	32 123	13 913	62 691	11 705
1970	27 619	20 814	56 212	28 356
1974	28 776	38 392	60 471	31 177
1975	29 663	41 109	36 790	18 418
1976[p]	39 909	21 923	..	..

Source: Statistics Canada.
[1]Chromium content; [2] Gross weight.
[p] Preliminary; .. Not available.

In 1966 the United Nations placed an embargo on exports from Rhodesia. Since Rhodesia, at that time, was the largest supplier of metallurgical-grade chromite the sanctions significantly affected the pattern of world trade. The United States was probably most seriously affected because it relied in large part on metallurgical-grade chromite produced in Rhodesia by subsidiaries of United States-based companies. While the United States observed the embargo, its ferrochromium industry experienced little growth, with the bulk of the incremental needs being supplied by imports from the other major producing countries. In 1972, the United States' ban on the import of Rhodesian chromite was lifted as a result of the passage by Congress of the Byrd Amendment. Since that time, pressure to end United States imports from Rhodesia has been increasing, to a point in 1975 when African leaders in Rhodesia threatened Union Carbide that if it did not stop importing chromite from its Rhodesian mines, it would face the total loss of supplies from any future African government in Rhodesia. In the United States a Congressional delegation presented a bill in 1975 that sought to reimpose sanctions against Rhodesia. The bill was narrowly defeated in the House of Representatives in September of that year. However, in March, 1977 the Byrd Amendment was finally repealed and the United States required that chromium bearing materials imported into the country have a certificate of origin proving that the chromium was not from Rhodesia. It is required that chromium ore and ferrochromium imported from South Africa be chemically tested to ensure that it is not of Rhodesian origin.

Chromite from the U.S.S.R. ranges, in Cr_2O_3 content, from 30 to 56 per cent. Exports for 1976 were estimated to be over 1 million tonnes, of which more that 80 per cent was shipped to Western countries. The latest Soviet five-year plan 1976-80 calls for 2.3 million tonnes of chromium ore production a year by 1980. Exports at that time are expected to account for 60 per cent of production. Most Soviet ores can be shipped without beneficiation, aside from hand picking. Over 90 per cent of the Soviet chromite output comes from the Donskay mining and concentrating complex at Khrom-Tau in Aktyubinsk Oblast of Kazakhstan. The first chromite concentrator to be built in the U.S.S.R. is under construction at Khrom-Tau. The first stage, with a capacity of 300 000 tonnes a year, was commissioned in 1974. When the second stage is completed in 1980 the total capacity will be 688 000 tonnes a year of marketable chromite. Discussions continued during the year with ferroalloy producers in Japan, Europe and the United States on the construction of ferrochromium plants within the U.S.S.R. For any technical services rendered, the U.S.S.R. would prefer to pay in terms of product from the plant concerned.

In Turkey, chromite production from both state and private concerns reached the one-million-tonne level during 1976. Turkish chromite is of the lumpy metallurgical type and has a grade of 46 per cent or more Cr_2O_3. The country's ferrochromium industry is in the process of expanding capacity at a new plant near Elazig which will produce about 55 000 tonnes a year when completed. Technical assistance for the planned expansion is being supplied by the Japanese company, Mitsubishi Corporation. In keeping with a policy of source diversification, Japanese chromium consumers have formed the Japanese Overseas Development Company to explore for and develop Turkish chromite deposits.

Nearby in Greece, the Hellenic Industrial and Mining Investment Company (HIMIC) has decided to build a ferrochromium plant with a 300 000-tonne-a-year capacity. During the initial period of start-up some chromite ore will be imported; however, the plant ultimately will be based exclusively on Greek chromite. Interest has been shown by various foreign firms dealing with ferroalloys with a view to participation in, and promotion of, this project.

The government of India is continuing plans for further restriction on chromite ore exports because of the strategic importance of the mineral. The possible limits could be 181 400 tonnes for high-quality ore shipments, 45 400 tonnes for low-quality, and 36 300 tonnes for low-quality-lump ore shipments. Exports of high grade lumpy ore are already banned from export. Japan continued to be India's biggest foreign market by importing some 245 000 tonnes of Indian ore.

The Philippines produce both refractory- and metallurgical-grade chromite. Total production during

1976 was some 399 000 tonnes, which included 270 700 tonnes of refractory-grade ore from the operations of Consolidated Mines Inc. at Coto Zambales. The newest producer of metallurgical ore, Perlite Minerals, started mining operations in August 1975 from a small deposit near Davau; the deposit reserves are estimated at 300 000 tonnes.

Malagasy Republic reports that production from the state-owned operations at Andriamena totalled some 217 800 tonnes, most of which was exported to Japan. Pakistan produced 20 000 tonnes of chromite ore in 1976, and with the help of West Germany will have a 15 000-tonne-a-year ferrochromium plant operating in 1977. In Kenya, three Japanese companies — Nippon-Kokan-Kaisha, C. Itoh and Co., and Kokan Mining Co. — have been surveying chrome deposits at West Pokot. It is hoped that a company will be formed to start commercial production by 1977. New Caledonia may have a revived chromite production if the two-year, $3 million combined exploration program and feasibility study warrant it. The program, which centres on the closed chromite mine at Tiebagi, is being carried out by three French companies.

Uses and technology

There are three commercial grades of chromite ore: metallurgical, refractory and chemical. Though interchangeable to a limited extent, each has a well-defined field of application.

Metallurgical-grade chromite is used primarily in the production of ferroalloys, but some is also used in the production of chromium metal. The principal ferroalloys produced are high-carbon (HC) ferrochromium, low-carbon (LC) ferrochromium and ferrochromium-silicon.

As a constituent of iron castings, steels and superalloys, chromium increases resistance to oxidation and corrosion and enhances their ability to withstand stress at high temperatures. In addition, chromium helps to refine the grain structure in iron castings.

The principal use of chromium ferroalloys is in the production of stainless and heat-resisting steels. Most applications of stainless and heat-resisting steels are in corrosive environments, e.g., petrochemical processing; high-temperature environments, e.g., turbines and furnace parts; and consumer goods areas, e.g., cutlery and decorative trim. Chromium is added to alloy and tools steels to increase harden-ability and to improve some mechanical properties such as yield strength. Superalloys containing chromium have a high degree of resistance to oxidation and corrosion at elevated temperatures and are used in jet engines, gas turbines and chemical processing. Chromium-containing castings are usually used for high-temperature applications.

The development of the argon-oxygen decarburization (AOD) step in the manufacture of stainless and heat-resisting steels has prompted major changes in chromium usage. The AOD process, which was developed by Union Carbide Corporation and Joslyn Stainless Steels Division of Joslyn Mfg. & Supply Co., is essentially a refining step after the charge has been melted down. Argon, an inert gas, is used along with oxygen so that carbon instead of chromium will be preferentially oxidized. Among other benefits, this serves to increase the recovery of chromium in the steels.

The ability to use charge chrome, which requires less energy to produce than the other chromium ferroalloys, and the reduction in the total amount of ferroalloys required, should lead to a quick adoption of technologies similar to the AOD step. The overall advantages obtained are lower cost of chromium additions, and in major stainless steel-producing countries

Table 3. Chromite ore grades

Metallurgical Grade	Refractory Grade	Chemical Grade
$>48\%\ Cr_2O_3$ (30.5% Cr)	Approx. 32% Cr_2O_3	Approx. 45% Cr_2O_3
>2.8 Cr:Fe ratio	Approx. 25% Al_2O_3	$<20\%$ Fe (total)
$<3\%\ SiO_2$*	$<12\%$ Fe (total)	Cr:Fe $\approx 1.6{:}1$
$<25\%$ MfO+ Al_2O_3+ CaO	$<6\%\ SiO_2$	$<15\%\ Al_2O_3$
$<0.1\%$ P		$<5\%\ SiO_2$
$<0.1\%$ S		
Preferably hard and lumpy ore	Preferably hard and lumpy ore	Friable ores acceptable

Note: > greater than, < less than, ≃ approximately, Cr — Chromium, Si — Silicon, Fe — Iron, P — Phosphorus, O — Oxygen, Ca — Calcium, Mg — Magnesium, S — Sulphur

Source: Department of Energy, Mines & Resources, Ottawa.
*Undesirable.

where electricity is expensive or in short supply, some savings in energy consumption required for the production of ferroalloys. Another process, similar to AOD refining, is the Creusot-Loire-Uddleholm (CLU) process which is being developed commercially by some European steelmakers.

In effect, these developments mean that the growth rate of chromium usage will be less than that of stainless steel because of the more efficient use of chromium additions.

The refractory industry uses chromium in the form of chromite, principally in the manufacture of refractory bricks. Some chromite is employed for refractory purposes in mortars and in ramming, castable and gunning mixes, or directly for furnace repair.

Refractories composed of both chromite and magnesite are used principally in applications where basic slags and dust are encountered. The principal areas of use are in the ferrous and nonferrous metal industries. In the ferrous industry, chrome-magnesite brick is used in the basic open hearth and basic electric furnaces. The declining importance of the basic open hearth in steelmaking had led to a decline in the amount of chromite used as a refractory in the steel industry. The continuing decline in open-hearth production will be partially compensated for by the increase in electric furnace production and a slower decline or, possibly, a stabilization, of chromite refractory consumption in the steel industry should result in the next few years. In the nonferrous industry, chrome-magnesite brick finds its principal use in converters. If oxygen-blowing in converters becomes economically feasible, the higher operating temperatures generated may necessitate a change to a higher-magnesite-content brick and thereby decrease chromite refractory usage.

The glass industry uses some chrome-magnesite brick in the reheating chambers of glass furnaces, and the kraft paper industry uses a dense chromite brick in recovery furnaces to resist chemical attack by spent liquors.

Chromite mortars and gunning mixes are used in the bonding and coating of basic bricks, or in areas where separation of various types of bricks by a chemically neutral substance is desirable. Castables and ramming mixes find their chief use in the open-hearth furnace.

Chromium chemicals have a wide variety of applications in a number of industries. Most chromium chemicals are derived from sodium dichromate, which is manufactured directly from chemical-grade chromite. The principal uses of chromium compounds are: in pigments, as mordants and dyes in the textile industry; as a tanning agent for all types of leathers, and in chrome electroplating, anodizing and dipping of various products. Among other uses, chromium compounds are used as oxidants and catalysts in the manufacture of various products such as saccharin; in the bleaching and purification of oils, fats and chemicals; and as an agent to promote the water insolubility of various products such as glues, inks and gels.

Prices

Chromite ore prices remained relatively stable during 1976; both Russia and Turkey maintained 1975 prices (fob) of $150 per tonne and $130-140 per tonne, respectively, for metallurgical-grade ore. The Philippines, after seeking an increase to $130 per tonne, settled for a price of $120 per tonne with its Japanese customers.

Ferrochromium demand was down throughout most of the year, as stainless steel producers drew from alloy stocks, which in some cases were equivalent to a six-month supply. Early in the year, competition in low-carbon ferrochromium was such that one producer suspended its list prices in order to remain flexible, while two others cut prices by as much as 7 cents per pound. During the year Union Carbide offered special three-year contracts to major customers. However, there was no great rush by steelmakers to sign Carbide's contracts, mainly because of the unclear outlook for the stainless steel industry.

By year-end, inventory clearance sales pushed the price of ferroalloys so low that Japanese alloyers formed an export cartel to set minimum prices for exports.

Outlook

Since almost 70 per cent of the chromium produced in the world is used in steel production, its future is closely tied to that of steel. The steel industry in general is now enduring a period of depressed demand and there are only minimal signs of an immediate short-term recovery. Stockpiles of specialty steels and chromium ore and alloys are very evident. Increases in production and price can only follow as stock piles are reduced. Also, since the repeal of the Byrd Amendment in the United States during the first quarter of 1977, prices have increased in a declining market.

The long term poses even more important factors in view of the fact that the Republic of South Africa has the same problems as those of Rhodesia. The critical question is how South Africa will respond to political pressures similar to those now being brought to bear on Rhodesia. South Africa has the majority of the world's known chromite reserves, and already has a severe shipping problem which will probably not be lightened until early in the 1980s, by which time political problems may be an insurmountable barrier.

Chromium is a much-needed commodity and the future will bring a diversification of supplies through expanded exploration activities and development of known deposits in all parts of the world.

Prices

Chrome prices published by "Metals Week"

	December 31, 1975	December 31, 1976
Chrome ore, dry basis, fob cars Atlantic ports	($ U.S.)	
Transvaal 44% Cr_2O_3, no ratio (per long ton)	37.00 – 52.00	38.00 – 46.00
Turkish 48% Cr_2O_3, 3:1 ratio (per long ton)	132.00 – 142.00	132.00 – 142.00
Russian 54-56% Cr_2O_3, 4:1 ratio (per metric ton (tonne))	150.00	150.00
Chromium metal	($ U.S.)	
Electrolytic 99.8%, fob shipping point (per lb)	2.44	2.63
Ferrochrome, fob shipping point (per lb Cr content)	(¢ U.S.)	
High carbon 67-70% Cr, 5-6% C	54.0 – 61.0	35.25
Imported charge chrome	44.0 – 50.0	35.5 – 37.0
Low carbon 67-73% Cr, 0.025% C	97.00	90.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Chrome ore	free	free	free	free
34700-1	Chromium metal in lumps, powder, ingots, blocks or bars, and scrap alloy metal containing chromium for use in alloying purposes	free	free	free	free
37506-1	Ferrochrome	free	5%	5%	free
92821-1	Chromium oxides and hydroxides With the following exceptions:	free	15%	25%	free
	For use in the manufacture of artificial resins and plastics	free	free	25%	free
	For use in the manufacture of additives for heating, lubricating and fuel oils	free	5%	25%	free
	Chromic oxide; chromium trioxide	10%	15%	25%	10%
92838-8	Chromium potassium sulphate	free	free	10%	free
92838-9	Chromium sulphate, basic	free	free	10%	free

United States

Item No.		Noncommunist Countries
601.15	Chrome ore	free
607.30	Ferrochromium, not containing over 3% by weight of carbon	4%
607.31	Ferrochromium, containing over 3% by weight of carbon, on chromium content	0.625¢ per lb
632.18	Chromium metal, unwrought (duty on waste and scrap suspended)	5%
632.84	Chromium alloys, unwrought	9%
420.98	Chromate and dichromate	0.87¢ per lb
473.10	Chrome colours	5%
531.21	Chrome refractories	12.5%

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), TC Publication 749.

Clays and Clay Products

G.O. VAGT

Clays are natural, earthy, fine-grained minerals of secondary origin composed mainly of a group of hydrous aluminum silicates and may contain iron, alkalis and alkaline earths. The clay minerals, formed by the chemical weathering or alteration of aluminous minerals such as feldspar and mica, are generally classified into three major groups based on detailed chemistry and crystalline structure — the kaolinite group, the montmorillonite group and the illite group. Clay deposits suitable for the manufacture of ceramic products may include nonclay minerals such as quartz, calcite, dolomite, feldspar, gypsum, mica, iron-bearing minerals and organic matter. The nonclay minerals may, or may not, be deleterious, depending upon individual amounts present and on the particular application for which the clay is intended.

The commercial value of clays, and of shales that are similar in composition to clays, depends mainly on their physical properties — plasticity, strength, shrinkage, vitrification range and refractoriness; fired colour, porosity and absorption; as well as on the proximity of any given deposit to urban growth centres in which clay products will be consumed.

Uses, type and location of Canadian deposits

Common clays and shale. Common clays and shales are the principal raw materials available from Canadian deposits for the manufacture of clay products. These materials are usually higher in alkalis, alkaline materials and iron-bearing minerals and much lower in alumina than the high-quality kaolins, fire clays, ball clays and stoneware clays. Common clays and shales are found in all parts of Canada, but deposits having excellent drying and firing properties are generally scarce and new deposits are continually being sought.

The clay minerals in common clays and shales are chiefly illitic or chloritic. Their fusion points are low, usually well below pyrometric cone equivalent number 15 (PCE 15)*. The presence of iron usually results in a salmon or red fired colour.

Suitable common clays and shales are utilized in the manufacture of heavy clay products such as common brick, facing brick, structural tile, partition tile, conduit tile, quarry tile and drain tile. Some Canadian common clays are mixed with stoneware clay for the manufacture of facing brick, sewer pipe, flue lining and related products. The raw materials utilized in the heavy clay industry usually contain up to 35 per cent quartz. If the quartz, together with other nonplastic materials, exceeds this percentage, the plasticity of the clay is reduced and the quality of the ware is lowered. If calcite or dolomite is present in sufficient quantities, the clay will fire buff-coloured and the fired strength and density will be adversely affected.

Most of the surface deposits of common clays in Canada are the result of continental glaciation and subsequent stream transport. Such Pleistocene deposits are of interest to the ceramic industry and include stoneless marine and lake sediments, reworked glacial till, inter-glacial clays and floodplain clays. These deposits are characterized by low melting temperatures.

The common shales provide the best source of raw material for making brick. In particular, those found in Cambrian, Ordovician and Carboniferous rocks in eastern Canada, and Jurassic, Cretaceous and Tertiary rocks in western Canada, are utilized by the ceramic industry. In many instances these shales are more refractory than the Pleistocene clays.

China clay (kaolin). China clay is a high-quality white, or nearly white, clay formed from the decomposition of the mineral feldspar, a major constituent of granite. The natural decomposition process, known as kaolinization, results in a hydrated aluminum silicate

*A convenient method of relating temperature and time by a single value. PCE 15 is defined by a temperature of approximately 1430°C and is the lower limit of the softening point of fire clays.

($Al_2O_3.2SiO_2.2H_2O$) with the following approximate composition: 40 per cent Al_2O_3, 46 per cent SiO_2 and 14 per cent H_2O.

None of the crude kaolins known to exist in Canada have been developed, primarily because of beneficiation problems and the small size of some of the deposits. Most occurrences contain a high proportion of quartz particles of varied sizes; mica, feldspar, magnetite, pyrite and colloidal iron have been noted as well. In the crude material the percentage of kaolinite frequently is small, making removal of impurities from Canadian kaolins difficult.

China clay is used primarily as a filler and coater in the paper industry, a raw material in ceramic products, and a filler in rubber and other products. The following properties are required in clays used by the paper industry: low-viscosity characteristics when in clay-water systems, intense whiteness, high coating retention, and freedom from abrasive grit. In the ceramic industry china clay is used as a refractory raw material. In prepared whiteware bodies such as wall tile, sanitaryware, dinnerware, pottery and electrical porcelain, quantities of nepheline syenite, silica, feldspar and talc are used as well.

Table 1. Canada, production of clay and clay products from domestic sources, 1974-76

	1974r	1975	1976p
		($000)	
Production from domestic sources, by provinces			
Newfoundland	436	457	475
Nova Scotia	742	3 155	3 915
New Brunswick	1 244	1 310	2 464
Quebec	12 194	16 468	14 243
Ontario	37 969	44 769	50 926
Manitoba	1 366	1 386	1 318
Saskatchewan	2 406	2 730	3 098
Alberta	5 964	8 530	8 727
British Columbia	4 732	7 172	6 944
Total Canada	67 053	85 977	92 110
Production[1] from domestic sources, by products			
Clay- fireclay and other clay	776	1 088	1 124
Firebricks and fireclay blocks and shapes	1 254	1 677	1 759
Brick-soft mud process	2 065	3 632	3 362
-stiff mud process	35 862	46 937	49 767
-dry press	7 834	10 260	10 878
-fancy and ornamental, sewer brick and paving brick	601	756	820
Structural hollow blocks	88	269	203
Drain tile	7 047	6 335	8 234
Sewer pipe	5 173	7 819	7 737
Flue linings	2 751	3 129	3 565
Pottery (glazed and unglazed including earthenware, sanitaryware, stoneware, flowerpots, etc.)	3 602	4 075	4 661
Total	67 053	85 977	92 110

Source: Statistics Canada, with breakdown of production by products by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1] Producers' shipments. Distribution for 1976 estimated by Mineral Development Sector.
p Preliminary; r Revised.

Table 2. Canada, imports and exports of clay, clay products and refractories, 1975-76

	1975		1976[p]	
	(tonnes[1])	($000)	(tonnes)	($000)
Imports				
Clays				
Bentonite	242 183	4 789	274 096	5 288
Drilling mud	14 471	5 324	28 733	7 458
China clay, ground or unground	148 378	6 783	176 751	7 340
Fire clay, ground or unground	43 320	1 861	33 340	1 319
Clays, ground or unground	137 289	3 866	146 487	4 303
Clays and earth, activated	43 870	4 511	92 496	4 920
Subtotal, clays	629 511	27 134	751 903	30 628
	(M)		(M)	
Clay products				
Brick-building, glazed	5 153	352	3 327	262
Brick-building, nes	161 896	3 251	714 831	4 831
Building blocks	. .	690	. .	1 169
Clay bricks, blocks and tiles, nes	. .	2 385	. .	3 515
Earthenware tile	(m^2)		(m^2)	
under 2½" x 2½"	1 480 102	5 870	1 661 522	5 447
over 2½" x 2½"	3 687 078	12 907	4 549 509	13 855
Subtotal, brick, blocks, tile	..	25 455	..	29 079
Tableware, ceramic	..	49 672	..	53 533
Porcelain, insulating, fitting	..	9 589	..	9 335
Pottery settings and firing supplies	..	580	..	756
Subtotal, porcelain pottery	..	59 841	..	63 624
	(tonnes)	($000)	(tonnes)	($000)
Refractories				
Firebrick				
Alumina	41 998	11 449	28 934	8 580
Chrome	3 923	1 171	3 676	1 604
Magnesite	22 360	9 439	16 110	7 621
Silica	17 071	7 303	10 850	3 671
nes	144 311	22 947	129 955	22 798
Refractory cements and mortars	..	5 822	..	6 322
Acid-proof brick	..	235	..	149
Crude refractory material	5 867	996	7 327	712
Grog (refractory scrap)	14 861	1 006	15 618	967
Refractories, nes	..	4 821	..	3 599
Subtotal, refractories	..	65 189	..	56 023
Total, clay, clay products and refractories	..	117 619	..	179 354

Table 2. (cont'd)

	1975		1976[p]	
	(tonnes)	($000)	(tonnes)	($000)
Imports (concl'd)				
By main countries				
United States	..	89 448	..	94 774
United Kingdom	..	39 027	..	33 206
Japan	..	19 498	..	16 144
Italy	..	8 265	..	9 564
West Germany	..	6 295	..	8 881
Greece	..	2 515	..	2 456
Spain	..	1 760	..	2 089
France	..	1 377	..	1 818
Austria	..	1 266	..	1 673
South Korea	..	803	..	1 342
Other countries	..	7 365	..	7 407
Total	..	177 619	..	179 354
Exports				
Clays, ground and unground	2 798	91	988	100
	(M)		(M)	
Clay products				
Building brick clay	7 227	1 322	5 026	1 319
Clay bricks, blocks, tiles, nes	..	358	..	301
Subtotal, bricks, blocks, tiles	..	1 680	..	1 620
High-tension insulators and fittings	..	2 396	..	2 845
Tableware	..	3 256	..	4 396
Subtotal porcelain tableware	..	5 652	..	7 241
	(tonnes)		(tonnes)	
Refractories				
Firebrick and similar shapes	48 802	12 615	39 425	10 907
Crude refractory materials	536 208	1 707	820 645	1 840
Refractory nes	..	2 734	..	2 960
Subtotal refractories	..	17 056	..	15 707
Total clays, clay products and refractories	..	24 479	..	24 668

Table 2. (concl'd)

	1975		1976^p	
	(tonnes)	($000)	(tonnes)	($000)
Exports (concl'd)				
By main countries				
United States	..	15 157	..	16 875
Dominican Republic	..	854	..	1 478
Australia	..	291	..	502
Colombia	..	67	..	478
United Kingdom	..	231	..	368
Iran	..	247	..	353
Mexico	..	351	..	270
South Africa	..	710	..	257
Guatemala	..	65	..	210
Costa Rica	..	60	..	192
Peru	..	194	..	180
Italy	..	301	..	174
Other countries	..	5 951	..	3 331
Total	..	24 479	..	24 668

Source: Statistics Canada.
^{p} Preliminary; .. Not available; nes not elsewhere specified; (M) = 1 000.
[1] The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Lower-quality kaolins in North America might be mined, and more expensive processing might be justified, as higher-quality deposits become depleted. If this situation arises, the development of a few Canadian deposits could become more attractive, particularly if new processing techniques and equipment become available.

In southern Saskatchewan, deposits of sandy kaolin occur near Wood Mountain, Fir Mountain, Knollys, Flintoft and other localities. Despite considerable work, no satisfactory method of producing a good commercial kaolin from these deposits has been developed.

A deposit of refractory clay which is very plastic to very sandy, and similar to a secondary china clay, occurs along the Fraser River near Prince George, British Columbia. This material has been investigated as a source of kaolin, as a fire clay and as a raw material for facing brick.

Various kaolinitic-rock deposits have been investigated in Manitoba. The reported deposits are principally in the northwest at Cross Lake and Pine River, on Deer Island (Punk Island) and Black Island in Lake Winnipeg, and at Arborg.

Several companies have shown considerable interest in Quebec's kaolin-bearing deposits although the deposits, in general, contain an excessive amount of quartz and iron minerals. Kaolin-bearing rock occurs at St-Remi-d'Amherst, Papineau County; Brébeuf, Terrebonne County; Point Comfort, on Thirty-one Mile Lake, Gatineau County; and Chateau-Richer, Montmorency County.

Extensive deposits of kaolin-sand mixtures occur in northern Ontario along the Missinaibi and Mattagami rivers. Although some encouraging results were obtained, distance from markets and the difficult terrain and climate of the area have hindered development. The kaolin has good refractory characteristics and meets specifications for filler-grade material. Potential uses for the silica, which comprises 80 per cent of the deposit, include glass manufacture, abrasive flour and ceramic application.

Ball clay. Ball clays are a very fine-grained, sedimentary kaolinitic type of clay with unfired colours ranging from white to various shades of grey depending on the amount of carbonaceous material present.

Ball clays obtained in Canada are mineralogically similar to high-grade, plastic fire clay. They are composed principally of fine-particle kaolinite and quartz, with less alumina and more silica than kaolins. Ball clays are extremely refractory materials. In whitewares they impart a high green strength as well as plasticity to the bodies. Although white firing clays are most suitable, fired products, which are cream coloured, do not interfere with the quality of the whiteware products.

Ball clays are known to occur in the Whitemud Formation of southern Saskatchewan. Good-quality deposits are present at Willows, Readlyn, Big Muddy Valley, Blue Hills, Willow Bunch, Flintoft and other areas. Clay from the Willows area has been used for many years in the potteries at Medicine Hat and Vancouver; however, the lack of proper quality control, the distance from large markets and lack of reserves have been the principal disadvantages affecting the widespread use of this material. Some ball clays from the Flintoft area are used for white-to-buff facing brick and for household pottery and crocks.

Fire clay. Fire clays contain high percentages of alumina and silica. They may be sedimentary or residual in origin, plastic or nonplastic and are composed mainly of kaolinite. The classification of fire clays may be related to the composition, physical characteristics, refractoriness, use, or association with other minerals. Descriptive terminology includes plastic fire clay, nonplastic fire clay, high-alumina fire clay, or high-heat-duty fire clay. Fire clays are plastic when pulverized and wetted, rigid when subsequently dried, and or sufficient purity and refractoriness for use in commercial refractory products.

Canadian fire clays are used principally for the manufacture of medium- and high-duty firebrick and refractory specialties. High-duty refractories require raw materials having a PCE of about 31.5 to 32.5 (approximately 1 699° to 1 724°C). Intermediate-duty refractories require raw materials having a PCE of about 29 (approximately 1 659°C) or higher. Clays having a PCE of less than 29 but greater than 15 (approximately 1 430°C) may be suitable for low-duty refractories or ladle brick as well as for other clay products. Known Canadian fire clays are not sufficiently refractory for the manufacture of super-duty refractories without the addition of some very refractory material such as alumina.

Various grades of good-quality fire clay occur in the Whitemud Formation in southern Saskatchewan.

Good-quality fire clays occur on Sumas Mountain in British Columbia. Some fire clay from the Sumas deposit is exported to the United States, and a small quantity is used at plants in Vancouver.

Fire clay and kaolin occur in the James Bay watershed of northern Ontario along the Missinaibi, Abitibi, Moose and Mattagami rivers. Considerable exploration has been carried out in some parts of these areas in recent years.

At Shubenacadie, Nova Scotia some seams of clay are sufficiently refractory for medium-duty refractories. Research has indicated that these deposits may be suitable for production of ladle brick. Clay from Musquodoboit, Nova Scotia has been used by a few foundries in the Atlantic provinces, and the properties and extent of this clay were investigated by the Nova Scotia Department of Mines.

Ontario and Quebec have no producing domestic sources of fire clay. These provinces import most of their requirements from the United States.

Table 3. Canada, shipments of clay products produced from imported clay[1], 1973-75

	1973		1974		1975^p	
	(000 m^2)	($000)	(000 m^2)	($000)	(000 m^2)	($000)
Electrical porcelains[2]	..	20 154	..	26 260	..	28 138
Glazed floor and wall tile[2]	1 845	8 678	2 046	10 193	1 554	9 036
Sanitaryware[2,3]	..	33 215	..	37 208	..	37 238[4]
Pottery, art and decorative ware[5]	..	3 183	..	2 629	..	—
Pottery, other[5]	..	893	..	169	..	—

Source: Statistics Canada.
[1]Does not include refractories. [2]Includes shipments of establishments classified to other industries which manufacture these commodities as a secondary activity, as well as to industries classified to this industry. [3]Includes lavatories, toilet bowls, toilet tanks and urinals. [4]Value of urinals not included in 1975, due to confidentiality. [5]Includes shipments of establishments classified to clay products manufacturers (from imported clays) only.
^{p}Preliminary; .. Not applicable; — nil.

Table 4. Canada, shipments of refractories, 1973-75

	1973		1974		1975^p	
	(tonnes)	($000)	(tonnes)	($000)	(tonnes)	($000)
Firebrick and similar shapes[1]	134 951	27 274	135 330	31 306	129 057	36 707
Cement, mortars, castables	84 512	14 651	95 885	19 713	122 886	28 277

Source: Statistics Canada.
[1]Includes fire clay blocks and shapes, fire brick, etc., made from domestic clays, and rigid firebrick, stove linings and other shapes made from imported clays, chrome ore, magnesite etc. Silica brick not included.
^{p}Preliminary.

Table 5. Canada, clay and clay products production and trade, 1965, 1970, 1974-76

	Production					
	Domestic Clays[1]	Imported Clays[2]	Total	Refractory Shipments[3]	Imports[4]	Exports[4]
			($ million)			
1965	42.8	31.4	74.2	27.4	59.4	10.3
1970	51.8	33.6	85.4	42.3	81.2	15.6
1974	67.1	56.7	123.8	61.5	158.0	24.4[r]
1975	86.0	59.1	145.1	69.9	177.6	24.5
1976[p]	92.1	..	..	..	179.4	24.7

Source: Statistics Canada.
[1]Production (shipments) of clay and clay products from domestic material. [2]Production (shipments) of clay products from imported clays. [3]Includes firebrick and similar shapes, all types, refractory cements, mortars, castables, plastics, etc., plus all other products shipped. [4]Includes refractories.
[r] Revised; [p]Preliminary; .. Not available.

Stoneware clay. Stoneware clays are similar to low-grade plastic clays and are characterized by good plasticity, a vitrification range between PCE 4 and 10, a long firing range and a fired colour from buff to grey. They range from commercially inferior material through semirefractory to firebrick clays. They should have low fire shrinkage, enough plasticity and toughness for shaping, no lime- or iron-bearing concretions and very little coarse sand.

Stoneware clays are used extensively in the manufacture of sewer pipe, flue liners, facing brick, pottery, stoneware crocks and jugs, and chemical stoneware.

The principal source of stoneware clay in Canada is the Whitemud Formation in southern Saskatchewan and southeastern Alberta. The Eastend area in Saskatchewan was formerly the source of much of the clay used at Medicine Hat. Stoneware clay pits are located in the Alberta Cypress Hills, southeast of Medicine Hat; and at Avonlea, Saskatchewan. Stoneware clays also occur on Sumas Mountain, near Abbotsford, British Columbia. These clays are used in the manufacture of sewer pipe, flue lining, facing brick and tile.

In Nova Scotia, stoneware clays occur at Shubenacadie and Musquodoboit. The Shubenacadie clays are used principally for the manufacture of buff facing brick. Other similar deposits occur at Swan River, Manitoba, where some buff brick has been manufactured; Kergwenan, Manitoba and in British Columbia at Chimney Creek Bridge, Williams Lake, Quesnel and near the Alaska Highway at Coal River. Quebec and Ontario import stoneware clay from the United States for manufacture of facing brick and sewer pipe.

Canadian industry and developments

The value of clays and clay products produced from domestic sources in 1976 was nearly $92.1 million, up from the 1975 figure of nearly $86 million. Operators List 6, Ceramic Plants in Canada, (1975) published by the Department of Energy, Mines and Resources, Ottawa, indicates that there were 185 operating plants. Some plants manufacture more than one ceramic product or group of ceramic products. The distribution of production facilities in Canada is presented in Table 6.

The brick and tile manufacturing industry accounts for nearly 30 per cent of the ceramic plants in Canada. These plants manufacture clay products which include common brick, facing brick, structural tile, quarry tile and drain tile; primarily from local common clays and shales.

Thunder Brick Company in Thunder Bay, Ontario, is constructing a new combination face-brick and split-tile plant in Thunder Bay, Ontario. The plant will be located on the site of the former Rosslyn Brick Works and will be the first plant in North America equipped for automatic production of extruded split tiles. The plant will have a design capacity of approximately 20 million bricks a year.

Ceramco Canada Ltd. is constructing a ceramic tile plant at the Bécancour Industrial Park at Trois-Rivières, Quebec. Some United States markets, as well as Canadian markets, are expected to be served.

In recent years requirements for brick as a structural material in low- to medium-rise buildings have been emphasized. The use of an oversize "through the wall" (TTW) brick, which provides wall thickness, now provides a significant market for brick manufacturers.

Six plants manufacture sewer pipe from domestic common clay, shale and fire clay. Of the porcelain and pottery producers; sanitaryware plants, electrical porcelain plants, wall tile plants, dinnerware plants and the art potteries are the principal consumers of ceramic-grade china clay and ball clays. These raw materials are imported mainly from the United States and Britain. Some of the art potteries and one of the dinnerware plants imported unfinished ware and completed the manufacturing process by glazing or decorating.

Table 6. Distribution of production facilities for ceramic products in Canada, 1976

Ceramic Product	Number of Plants: Atlantic Provinces	Quebec	Ontario	Prairie Provinces	British Columbia	Total
Abrasives	—	5	10	—	—	15
Brick and Tile	4	7	32	5	3	51
Clay Sewer Pipe	1	—	2	2	1	6
Glass	1	5	9	4	2	21
Porcelain and Pottery	—	11	26	4	5	46
Porcelain Enamel	2	4	20	1	—	26
Refractories	—	5	12	1	4	22
	8	28	111	17	15	187

Note: Some plants produce more than one group of products.
Source: Based on Operators List 6, Ceramic Plants in Canada (1975), Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
— Nil.

Most of the refractory manufacturing plants utilize imported clay including ball clay, fire clay and kaolin, as the principal ingredients in many of their products. The nine abrasives plants utilized both domestic and imported raw materials. The distribution was approximately half and half, except for silicon carbide, which was supplied entirely from domestic sources; and petroleum coke, which was imported. Domestic and foreign sources of raw materials were used by Canadian glass plants. Those in Quebec and Ontario accounted for most of the imported silica sand used.

Porcelain enamel was produced and utilized at 26 plants.

World review

In the United States, there was some recovery in the level of activity in the construction industry. Mine production of clays increased to $53.0 million in 1976 from $49.1 million in 1975. The increase was almost evenly distributed among all types of clay, including bentonite and fuller's earth.

The major uses for specific clays in the United States are as follows: *kaolin,* paper manufacture, refractories, rubber manufacture; *ball clay* — dinnerware, sanitaryware, floor and wall tile; *fire clay* — firebricks, foundry sands; *bentonite* — iron ore pelletizing, foundry sand bonding, drilling mud; *fuller's earth* — absorbents and fillers, insecticide carriers; *common clay* — construction material.

Demand for clays is expected to increase at an annual rate of between two and five per cent through 1980. However, continued growth of the energy-intensive, clay-based industries could be severely impeded by persistent energy problems. Environmental problems and the need for planned land utilization must also be considered in any projection of future developments in the clay industry.

Clays were produced in 47 states at a total of 1 317 mines during 1976. Adequate reserves of high-quality clays of all types, together with possession of clay-processing technology, assure the United States a position as a major world supplier of clays.

The United States is the world's leading producer of kaolin, accounting for 5.2 million tonnes in 1976. The United Kingdom is the second-largest producer and is the leading exporter of kaolin, mainly to Europe, United States and Japan. Other major producers are the U.S.S.R., France, Czechoslovakia, West Germany and Spain. Japan depends mainly on the United States as a source of kaolin imports. Lesser amounts of kaolin are imported from South Korea, Britain and the U.S.S.R.

In Greece, kaolin production is mainly for domestic consumption.

The Netherlands does not produce kaolin, but acts as a very important distribution point for American and British clay entering Europe.

New kaolin-producing operations, and expansions to old plants, are occurring in non-traditional producing areas. The largest development was by National Bulk Carriers Inc., of New York. This company began operating a 245 000-tonne-a-year plant in Brazil. The new plant, Caulim de Amazonia, is located 60 miles north of the confluence of the Rio Jiri and the Amazon rivers.

The installation of magnetic separators continues at several kaolin processing plants in the United States. Eight new separators are expected to be in operation by the end of 1977. This technological development is a key element in producing better-quality coating clays, reducing chemical reagent consumption and extending mineral reserves.

Table 7. Canada, consumption (available data) of china clay, by industries, 1974-75

	1974	1975[p]
	(tonnes)	
Ceramic products	13 381	13 498
Paint and varnish	5 301	4 294
Paper and paper products[1]	109 126	85 570
Rubber and linoleum	3 846	3 470
Other products[2]	23 415[r]	19 009
Total	155 069[r]	125 841

Source: Statistics Canada. Component breakdown by Mineral Development Sector, Department of Energy. Mines and Resources, Ottawa.
[1]Includes paper and paper products and paper pulp. [2]Includes adhesives, chemicals, foundry, glass fibre, wire and cable, and other miscellaneous products.
[r] Revised; [p]Preliminary.

Outlook

Projections by industry suggest that new and repair construction expenditures in Canada will be greater than $34 billion in 1977, $2 billion more than in 1976. Real growth, however, may be negative. Housing starts alone are expected to be 15 per cent lower in 1977 than in 1976.

Brick prices are expected to increase from 5 to 10 per cent in mid-1977, according to one industry spokesman.

Kaolin, as well as other minerals such as perlite, gypsum, diatomite and various clays, is being used in growing quantities as a carrier for pesticides.

Demand for high-grade, super-duty refractories continued to be high through 1976 as indicated by imports of both alumina and magnesite firebrick. Steel processes such as the basic oxygen furnace, pressure pouring and continuous casting, represent relatively new refractory requirements. New products and designs have also been dictated by changes in reducing atmospheres in the chemical and petro-chemical industry, by increased demand for high-purity glass and by the need for more economical production of ceramics.

Better fuel management is currently very essential and will be more critical in the future. Research continues into the use of oxygen-enriched air in industrial processes such as ceramic and glass manufacture, as well as ferrous and non-ferrous metal foundry operations.

The few known deposits of fire clays and ball clays in the developed areas of Canada are being utilized. Much assessment work has been done on deposits containing kaolin but, because of small size, high cost of beneficiation, or remoteness from transportation or industry, none have been developed. Ontario and Quebec are particularly deficient in developed deposits of refractory- or kaolin-type clays.

Clay and shale, like other low-cost construction materials, must be produced near the heavily populated areas where the markets are situated. This necessary feature of the industry will continue to produce increasingly complex problems related to rising land costs, land-use conflicts, environmental control requirements, and cost of land rehabilitation. The situation is particularly acute in southwestern Ontario where suitable reserves of brick-shales and other construction materials are being depleted, with few prospects for the opening of new pits and quarries under present controls. Some end-use products such as brick and tile find competition from cement, glass, metals and plastic manufacturers; however, clays, being generally less expensive and very satisfactory for their intended uses, are usually able to hold their own, or to increase in usage at the expense of the alternate materials for many end-uses.

Bentonite and fuller's earth

Bentonite, a clay which consists, primarily of montmorillonite, a hydrous aluminum silicate with weakly attached cations of sodium and calcium, is reviewed in a separate section of the *Canadian Minerals Yearbook, 1976.*

Fuller's earth is primarily a calcium montmorillonite clay characterized by natural bleaching and absorbent properties; it is similar to nonswelling bentonite. The terminology is confusing and bentonite and fuller's earth may not necessarily be separated in world trade and production statistics by country. Attapulgite, a magnesium-aluminum silicate, is a form of high-quality fuller's earth.

Prices

United States clay prices, according to Chemical Marketing Reporter, December 27, 1976.

	($ per short ton)
Ball clay	
Domestic, crushed, moisture-repellent, bulk car lots, fob Tennessee	8 — 11.25
Imported lump, bulk, fob Great Lakes ports	40.50
Imported, airfloated bags, car lots, Atlantic ports	70.00
China clay (kaolin)	
Water washed, fully calcined, bulk car lots, fob Georgia	145 — 182.50
Uncalcined, No. 1 coating, same basis	61.50
Dry-ground, airfloated soft, fob Georgia	20.00

Tariffs

Canada

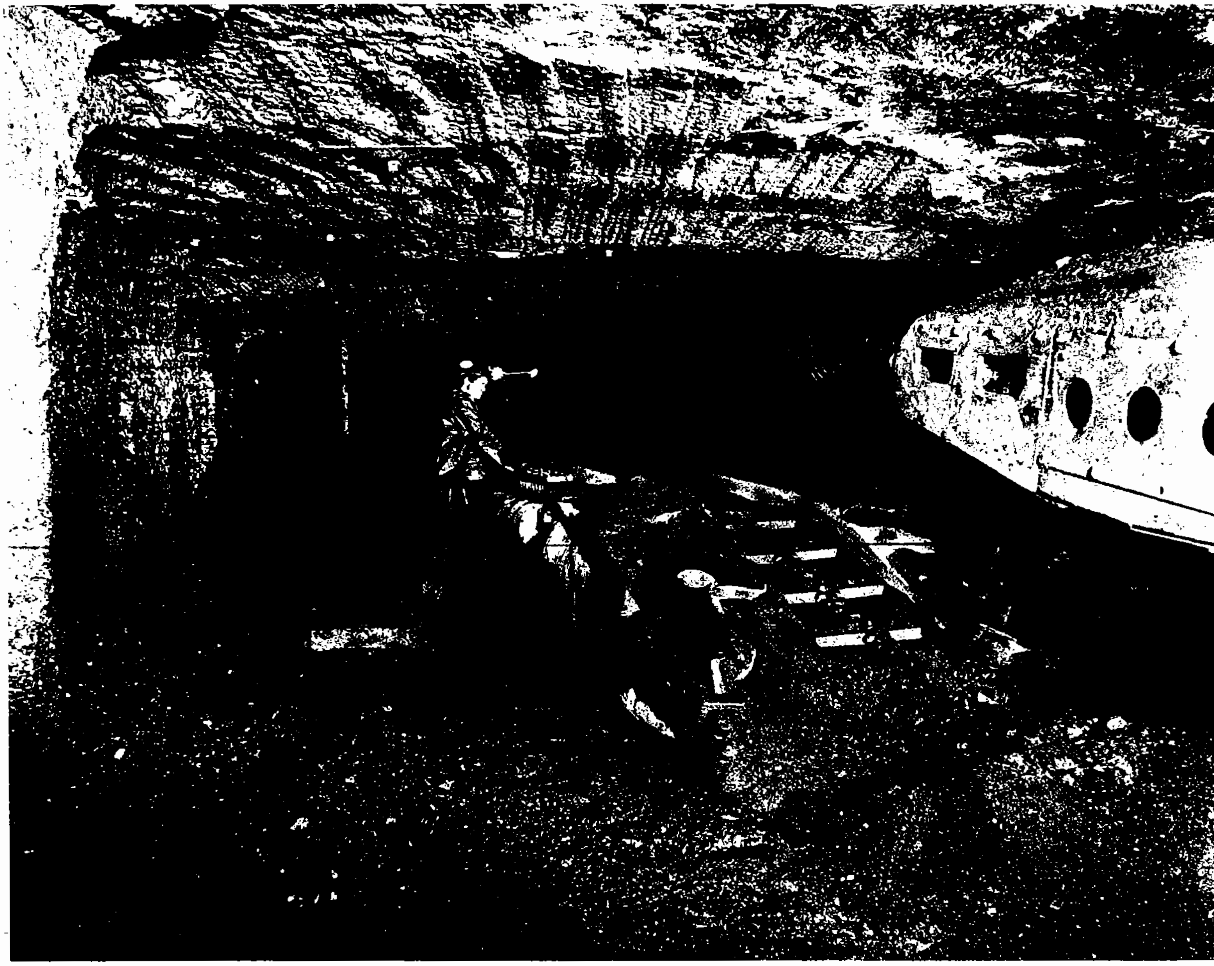
Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
29500-1	Clays, including fire clay, pipe clay not further manufactured than ground	free	free	free	free
29525-1	China clay	free	free	25	free
28100-1	Firebrick containing not less than 90 per cent silica; magnesite firebrick or chrome firebrick; other firebrick valued at not less than $100 per 1,000 rectangular shaped, not to exceed 100 X 25 in.[3] for use in kiln repair or other equipment of a manufacturing establishment	free	free	free	free
28105-1	Firebrick, nop, of a class or kind not made in Canada, for use in construction or repair of a furnace, kiln, etc.	free	free	15	free
28110-1	Firebrick, nop[1]	5	10	22½	5
28200-1	Building brick and paving brick	10	10	22½	6½
28205-1	Manufactures of clay or cement, nop	12½	12½	22½	8
28210-1	Saggars, hillers, bats and plate setters, when used in the manufacture of ceramic products	free	free	free	free
28300-1	Drain tiles, not glazed	free	17½	20	free
28400-1	Drain pipes, sewer pipes and earthenware fillings therefor; chimney linings or vents, chimney tops and inverted blocks, glazed or unglazed, nop	15	20	35	13
28405-1	Earthenware tiles, for roofing purposes	free	17½	35	free
28415-1	Earthenware tiles, nop	12½	20	35	12½
28500-1	Tiles or blocks of earthenware or of stone prepared for mosaic flooring	15	20	30	13
28600-1	Earthenware and stoneware, viz., demijohns, churns and crocks, nop	20	20	35	13
28700-1	All tableware of china, porcelain, semiporcelain or white granite, excluding earthenware articles	free	15	35	free
28705-1	Articles of chinaware, for mounting by silverware manufacturers	12½	17½	22½	11½
28710-1	Undecorated tableware of china, porcelain, semi-porcelain for use in the manufacture of decorated tableware	free	10	35	free
28800-1	Stoneware and Rockingham ware and earthenware, nop	17½	20	35	13
28805-1	Chemical stoneware	free	10	35	free
28810-1	Hand forms of porcelain for manufacture of rubber gloves	free	free	35	free
28900-1	Baths, bathtubs, basins, closets, closet seats and covers, closet tanks, lavatories, urinals, sinks and laundry tubs of earthenware, stone, or cement, clay or other material, nop	12½	15	35	12½

Tariffs (concl'd)

United States

		(¢ per long ton)
521.51	Fuller's earth, not beneficiated	25
521.41	China clay or kaolin	33
521.54	Fuller's earth, wholly or partly beneficiated	50
521.81	Other clays, not beneficiated	free
521.84	Other clays, wholly or partly beneficiated	50
521.61	Bentonite	40
521.71	Common blue clay and other ball clays not beneficiated	42
521.74	Common blue clay and other ball clays, wholly or partly beneficiated	85
521.87	Clays artificially activated with acid or other material	0.05¢ per lb.+ 6%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Ottawa. Tariff Schedules of the United States, Annotated (1976) T.C. Publication, 749.
[1]nop Not otherwise provided for.
Note: In addition to the above tariffs, various duties are in existence on manufactured clay products, viz., brick pottery, artware, etc.



At the Lingan Mine of the Cape Breton Development Corporation (DEVCO) a miner operates a mechanical loader to pick up the surge pile of coal cut from the tunnel by a continuous miner.

Information EMR photo

Coal and Coke

J.A. AYLSWORTH

The year 1976 was one of stability and expectation for Canada's coal industry. The volume and value of production increased marginally in the face of soft markets. Imports declined in volume and value, while exports showed a modest increase in volume and a significant increase in value. Two new major mines came on stream in Canada and the coal industry continued to experience a relatively high level of activity in exploration and feasibility studies. On the government side, Alberta released its coal policy while Nova Scotia, Saskatchewan and British Columbia continued to work towards policy documents. The provincial mines ministers met with their federal counterpart and agreed to work towards a national coal policy. Research on various aspects of coal conversion continued and an *in situ* coal gasification test program began in Alberta. The international coal market remained weak in response to slumping steel markets and most coal-importing countries were faced with growing coal stockpiles. Nevertheless, foreign interests carried on negotiations with several potential Canadian producers as the steel industry looked ahead to increased output in the 1980s.

In 1976 production of coal in Canada reached 25.5 million tonnes*, up marginally from 25.3 million tonnes in 1975. The value of production increased from $586 million in 1975 to $602 million in 1976, reflecting higher costs, prices and inflation. Both the volume and value of production increased in Nova Scotia, Saskatchewan and Alberta, while New Brunswick and British Columbia experienced lower outputs. British Columbia remained the largest producer in terms of value in spite of a decrease from $342 million in 1975 to $298 million in 1976. Canadian bituminous coal production declined by 8 per cent from 15.7 million tonnes in 1975 to 14.4 million tonnes in 1976. This decline reflected the strikes experienced by the major producers and the depression in the world steel industry. Subbituminous output increased by 7 per cent from 6.0 million tonnes in 1975 to 6.4 million tonnes in 1976. Lignite production experienced the largest growth rate, increasing by 34 per cent to 4.7 million tonnes in 1976 from 3.5 million tonnes in 1975. This increase reflected Manitoba's exceptional use of coal as low water levels reduced electricity output from hydro sources.

Exports increased slightly in 1976 to 11.8 million tonnes despite a decrease in shipments to Japan. The difference was made up by expanded exports to other markets including West Germany, Denmark, South Korea, Sweden and Mexico. While the volume of exports increased only slightly, the value increased by 17 per cent to $557 million from $477 million in 1975, reflecting higher prices brought on by inflation and increased production and transportation costs. Imports decreased to 14.6 million tonnes in 1976, down from 15.3 million tonnes in 1975.

Of the 27.8 million tonnes of coal consumed in Canada, 18.9 million tonnes were used to generate electricity in thermal power stations; 7.4 million tonnes were carbonized to make 5.3 million tonnes of coke and 1.5 million tonnes of anthracite and bituminous coal were consumed by general industrial and commercial users.

The average value of all types of coal in Canada rose from $23.22/tonne in 1975 to $23.65/tonne in 1976. Bituminous coals experienced significant increases with an average value of $39.13/tonne in 1976, up 12 per cent compared to $35.10/tonne in 1975. The average value of subbituminous coal increased 3 per cent to $4.14/tonne in 1976 from $4.03/tonne in 1975, while the average value for lignite also increased by 3 per cent from $2.72/tonne in 1975 to $2.79/tonne in 1976. Bituminous value increases reflected increased production and transportation costs. Subbituminous and lignite coals are primarily marketed to provincial utilities under long-term contracts, and their values are not generally subjected to large yearly fluctuations. The value of exports increased to $47.39/tonne in 1976 from $40.87/tonne in 1975, reflecting the high proportion of

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

bituminous coking coals, although Canada also exported some thermal coal in 1976.

The world coking coal market in 1976 reflected the depressed condition of the world steel industry. Many coal producers reduced or stabilized output and built up inventories as steel companies attempted to balance reduced coal requirements with relatively long-term contract commitments. Average base price per ton in the export market stabilized in 1976, but escalation clauses covering increased production and transportation costs resulted in an overall increase in the total price received by coking coal exporters. Lack of international interest in thermal coal reflected the ready availability of oil, while low spot prices for coking coals reflected the excess capacity and the beginning of the change from a sellers' to a buyers' market.

Table 1. Canada, coal production[1] by types, provinces and territories 1975-76

	1975[r]		1976[p]	
	(tonnes)	$	(tonnes)	$
Bituminous				
Nova Scotia	1 656 193	44 586 000	2 000 026	54 609 000
New Brunswick	418 502	7 100 000	296 349	6 432 000
Alberta	4 097 034	159 023 000	4 583 110	203 394 000
British Columbia	9 580 184	342 088 000	7 509 337	298 491 000
Total	15 751 913	552 797 000	14 388 822	562 926 000
Subbituminous				
Alberta	5 958 459	23 992 000	6 409 619	26 495 000
Lignite				
Saskatchewan	3 548 585	9 634 000	4 677 597	13 045 000
All types, Canada total	25 258 957	586 423 000	25 476 038	602 466 000

Source: Statistics Canada.
[1]Production represents clean coal output, plus raw coal sales from the mine where there is a preparation plant at the mine, plus raw coal shipments where there is no preparation plant at the mine.
[p]Preliminary; [r]Revised.

Table 2. Canada, coal production, imports, exports and consumption, 1966-76

	Production	Imports[1]	Exports	Domestic Consumption
		(tonnes)		
1966	10 142 210	14 911 173	1 114 767	22 942 765
1967	10 107 248	14 618 547	1 214 133	22 667 217
1968	9 969 059	15 464 547	1 312 707	24 782 275
1969	9 681 366	15 737 300	1 249 984	23 999 872
1970	15 063 044	17 112 932	3 983 967	26 773 320
1971	16 721 410	16 452 867	7 015 963	25 627 819
1972	18 787 175	17 476 814	7 723 229	25 757 783
1973	20 472 755	14 830 511	10 907 717	24 870 489
1974	21 269 588	12 381 118	10 774 106	24 844 710
1975	25 258 956	15 254 906	11 694 655	26 126 654
1976[p]	25 476 037	14 585 002	11 761 930	

Source: Statistics Canada.
[1]Coal imports for consumption; from the United States and United Kingdom.
[p]Preliminary; . . Not available.

Outlook

Total production of coal will likely increase in Canada in 1977 to an estimated 29 million tonnes. Exports during 1977 to Canada's traditional metallurgical market, Japan, will increase marginally over 1976 levels, while exports to other countries may increase by greater amounts in response to efforts by coal companies to diversify markets. The world steel industry appears to be in a holding pattern, with demand likely to increase slowly in 1977. Coal prices will increase marginally or remain static in real terms in response to excess production capacity, with some changes in contract terms and tonnages reflecting this fact.

Internally, the second full year of the Cape Breton Development Corporation's (Devco's) coal contract with The Steel Company of Canada, Limited saw approximately 250 000 tonnes moving to Hamilton by the St. Lawrence Seaway. Devco is also looking towards European and Latin American markets for its coking coal.

Production of coal for the generation of electricity is expected to increase in 1977, reflecting new capacity, fuller use of existing capacity and increased use on the prairies in response to low snowfalls during the winter of 1976-77. A new coal-powered generating unit is expected to come on stream in Saskatchewan in 1977 and stations in Alberta will increase consumption over 1976 levels. In eastern Canada production of coal for the thermal market will increase as Nova Scotia turns towards its domestic fuels to supplant foreign oil. Ontario Hydro's consumption of coal will increase in 1977 and for the next few years as new contracts with Alberta, British Columbia, Saskatchewan and United States mines provide more coal for existing and future generating units.

The pattern of Canadian exports into the 1980s will reflect world iron and steel markets which have recently experienced a recession. The Japanese iron and steel industry, which has been Canada's major coking coal market, will retain this position into and throughout the 1980s. Nevertheless, development of steel industries in third world countries also offers potential for Canadian coking coal exports. Expanded exports of thermal-grade coal from western and eastern Canada remains a possibility in the near future, although these movements will be conditioned by prices, by the distance to markets and by the restrictions imposed by the necessity of ensuring sufficient resources for long-term domestic demand.

Demand in central Canada will also create a growing market for expanded Canadian production in the 1980s. The recent decision by Ontario Hydro to establish a western delivery system including rail, port and lake vessel components, has helped make Canadian coals more competitive in central Canada despite their geographical remoteness. Several western Canadian coking coals have been evaluated by Canadian steelmakers and the option of using them to satisfy some of the incremental demand of an expanding domestic steel industry is now only conditioned by economics and quality considerations. Thus the acquisition of equity positions by Ontario steel concerns in western Canadian coal properties becomes more important as the supply of specific coking coals becomes more uncertain.

Gasification and liquefaction of coal may also play an important role in Canada's coal industry in the 1980s. These processes are presently the centre of considerable research and development work in many parts of the world, including Canada. *In situ* gasification tests in Alberta in 1976 and studies on Hat Creek coals in British Columbia are two of the many research projects now under way in Canada. Use of coal as a fuel in tar sands or heavy oil production may present further opportunities for Canada's coal resources.

The foregoing opportunities and potential demands represent just one side of Canada's expanding coal industry. The other side involves financial, manpower and equipment resources; governmental policies, infrastructure and institutional arrangements; environmental questions and reclamation requirements. Based on the large increases in production forecast for the early 1980s and beyond, manpower is likely to continue as a critical question for the Canadian coal industry unless adequate training programs are developed to meet the projected demands. Capital requirements for new mines have increased dramatically over the last three years and equipment is both expensive and in short supply. Some of the forecast coal developments may occur in areas requiring new transportation and townsite infrastructure, and all new developments will have to meet environmental, regional development, economic viability and other criteria of provincial and federal governments. While these and other considerations have stretched the lead time for new mines to four or more years, the potential for growth is demonstrated by the amount of exploration and other work now under way in many areas of Canada.

Provincial policies

In June 1976, Alberta released its coal policy, which had been nearly three years in preparation. The policy is based on the goal of bringing to the people of Alberta as owners of the resource, the maximum obtainable present and future benefits. No new coal developments will be permitted unless they can proceed without irreparable harm to the environment and with satisfactory reclamation of disturbed land. Development is to be permitted first to meet Alberta's own electric energy and industrial needs on a long-term basis, followed by other Canadian needs and finally, export demand. Developers will be required to make the maximum use of Alberta's manpower, services, materials and labour and to encourage equity ownership by provincial residents. A new royalty formula based on costs of production, gross revenue, and cumulative investment rep-

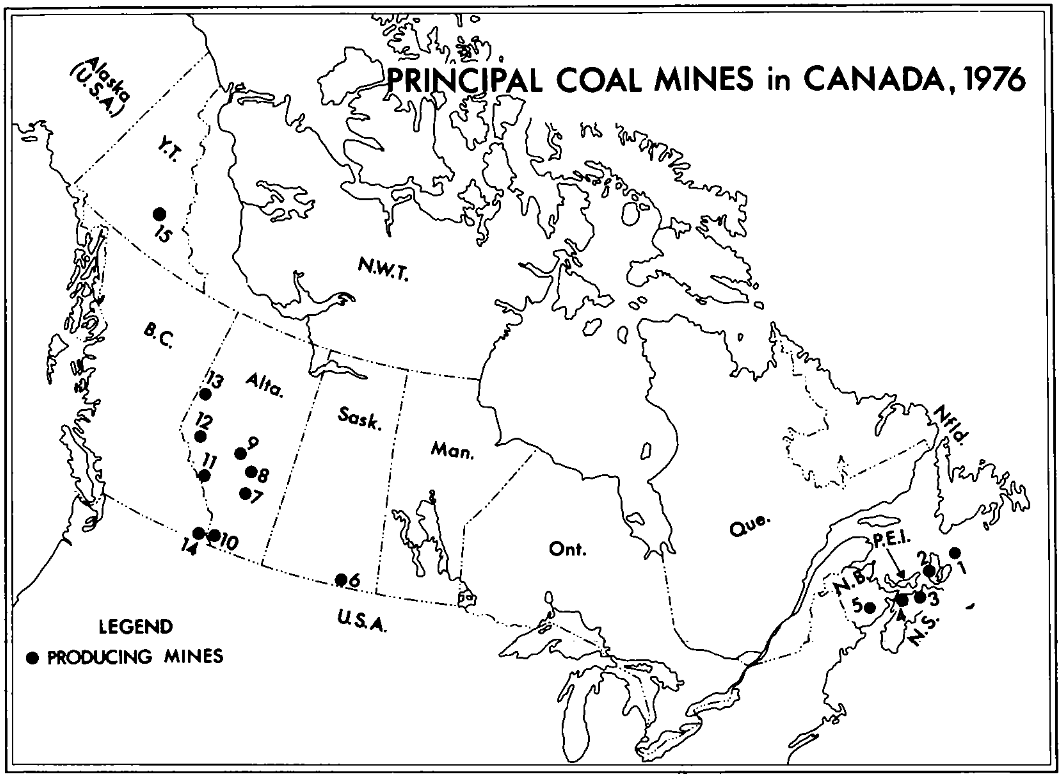


Table 3. Principal coal producers in 1976

Company and Mine Location	Estimated 1976 Raw coal Production	Coal Rank	Chief Markets	Remarks
(numbers refer to the map above)	(tonnes)			
Nova Scotia				
1. Cape Breton Development Corporation (DEVCO)				
Lingan Mine, Lingan	1 233 000	Hvb A	Power Generation	Underground
No. 26 Colliery, Glace Bay	808 000	Hvb A	Metallurgical, Industrial, Domestic	Underground
Prince Mine, Point Aconi	165 000	Hvb A	Power Generation	Underground
2. Evans Coal Mines Limited St. Rose	9 000	Hvb B	Power Generation, Residential	Underground

Table 3. (cont'd)

Company and Mine Location	Estimated 1976 Raw coal Production	Coal Rank	Chief Markets	Remarks
	(tonnes)			
3. Drummond Coal Company Limited, Drummond Westville	16 000	Mvb & Hvb A	Power Generation	Underground
4. River Hebert Coal Company Limited	30 000	Hvb A	Power Generation	Underground
New Brunswick				
5. N.B. Coal Limited Minto, Chipman areas	430 000	Hvb A	Power Generation Paper Mills	Surface, operates at 6 locations
Saskatchewan				
6. Manitoba and Saskatchewan Coal Co. (Limited) M&S Mine, Bienfait	763 000	Lig A	Power Generation Industrial	Surface
Boundary Dam Mine, Estevan	1 527 000	Lig A	Power Generation	Surface.
6. Manalta Coal Ltd. Klimax Mine, Estevan	1 140 000	Lig A	Power Generation Industrial	Surface
6. Manalta Coal Ltd., Utility Mine, Estevan	1 247 000	Lig A	Power Generation	Surface
6. Saskatchewan Power Corp., Souris Valley Coal Mine, Estevan	19 000	Lig A	Power Generation	Surface, began production in Nov. 1976
Alberta				
Subbituminous Mines				
7. Century Coals Limited Atlas Mine, East Coulee	42 000	Sub B	Residential, Power Generation	Underground
8. Manalta Coal Ltd. Roselyn Mine, Sheerness	362 000	Sub C	Power Generation	Surface
8. Manalta Coal Ltd. Vesta Mine, Halkirk	533 000	Sub C	Power Generation Residential	Surface
8. Forestburg Collieries Limited Diplomat Mine, Forestburg	773 000	Sub C	Power Generation, Residential	Surface
9. Manalta Coal Ltd. Whitewood Mine, Wabamun	2 059 000	Sub A & B	Power Generation	Surface
Highvale Mine, Sundance	2 589 000	Sub C	Power Generation	Surface

Table 3. (concl'd)

Company and Mine Location	Estimated 1976 Raw coal Production	Coal Rank	Chief Markets	Remarks
	(tonnes)			
Alberta (cont'd)				
Bituminous Mines				
10. Coleman Collieries Limited Vicary Creek, Coleman	166 000	Mvb	Japan for coke-making	Underground
Tent Mountain, Coleman	1 274 000	Mvb	Japan for coke-making	Surface
11. The Canmore Mines, Limited Canmore	91 000	An & Lvb	Japan for coke-making	Underground
12. Cardinal River Coals Ltd. Cardinal River Mine, Luscar	2 253 000	Mvb	Japan for coke-making	Surface
13. McIntyre Mines Limited Smoky River Mines, Grande Cache	2 073 000[1] 1 132 000	Lvb	Japan for coke-making	Surface and Underground
British Columbia				
14. Kaiser Resources Ltd. Michel Colliery, Natal	912 000	Lvb	Japan for coke-making	Surface and Underground (hydraulic mining, room-and-pillar)
Harmer Ridge, Sparwood	5 987 000	Lvb	Japan for coke-making	Surface
14. Fording Coal Limited Fording Mine, Fording Valley	2 401 000	Lvb	Japan for coke-making	Surface
Byron Creek Collieries Limited, Corbin	349 000	Mvb	Canada and Europe for thermal and coke making	Surface
Yukon				
15. Cyprus Anvil Mining Corporation, Tantalus Butte Coal Mine, Carmacks	27 000	Hvb B	Anvil lead-zinc mine for heating and concentrate drying	Underground

Sources: Data supplied by various companies to the Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Surface production.
An — Semi-anthracite; Lvb — Low volatile bituminous; Mvb — Medium volatile bituminous; Sub — Subbituminous; Lig — Lignite; Hvb — High volatile bituminous.

Table 4. Canada, coal production by rank, province, type of mining and average output per man-day, 1976

	Production^{p,1}		Average output per man-day^{e,2}	
	Underground	Surface	Underground	Surface
	(tonnes)			
Bituminous				
Nova Scotia	2 189 523	—	4.9	—
New Brunswick	—	429 967	—	6.4
Alberta	1 388 895	5 362 978	9.3	28.6
British Columbia	1 035 246	9 095 279	16.8	24.7
Subbituminous				
Alberta	40 559	6 369 060	9.5	66.5
Lignite				
Saskatchewan	—	4 677 597	—	84.7
Canada 1976^p	4 654 223	25 934 881	8.9	46.3
1975	4 048 089	26 706 855	8.6	53.5
Total, all mines				
1976^p	30 589 104		40.6	
1975	30 754 944		47.7	

Sources: Statistics Canada and Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Raw coal production only. [2]Mine production and related employment only, excludes preparation plant workers, executive administrative, sales and office employees. Man-day refers to approximately an eight-hour man-shift.
^{p}Preliminary; ^{e}Estimated; — Nil.

laces the old 11¢ per tonne royalty. The province has been divided into four zones or land classification regions for future exploration and development. The regulations on exploration and development in these zones vary from prohibiting all activities in some areas of the Foothills region; to limited access and development in others; to relatively few restrictions in the area of least environmental and social conflict.

During 1976 British Columbia released its *Guidelines for Coal Development.* While not a policy (this is expected in 1977) the guidelines were intended to outline the planning process required to achieve a rational approach to land use, environmental impacts and community developments resulting from new coal mining projects. The guidelines provide procedural direction for impact assessment and management, and specify the information required for review of the permit and licence applications which are required prior to new coal mine developments. The resulting procedure involves a four-stage assessment process beginning with a prospectus, followed by a preliminary and detailed assessment, and concluding with a project implementation stage.

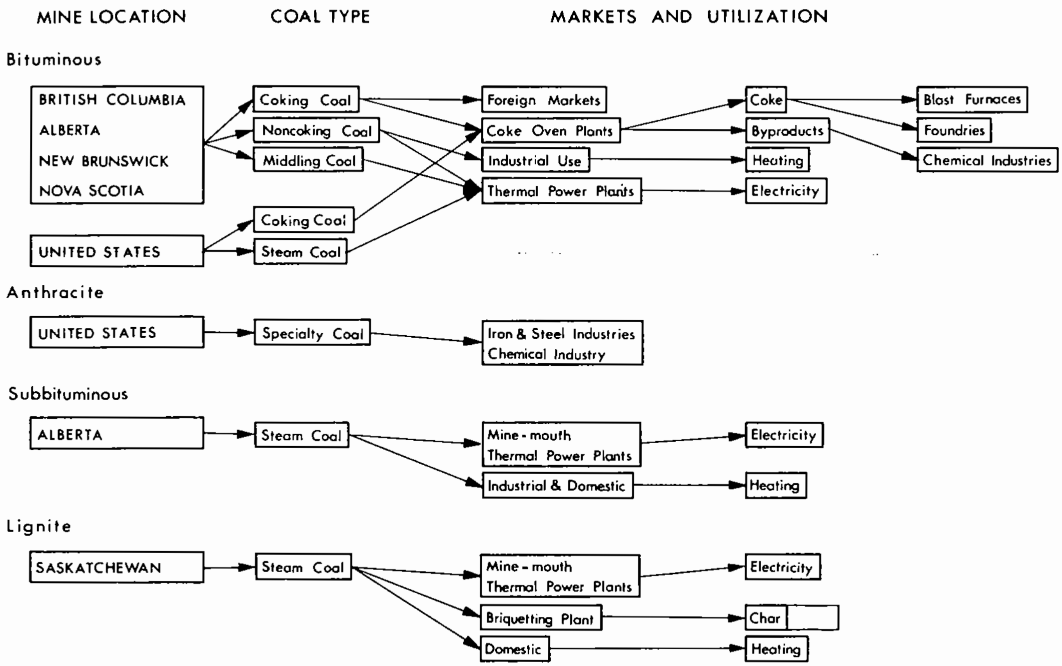
Saskatchewan was the third western province to produce legislation affecting its coal resources. In April 1976 Saskatchewan introduced a bill that would provide for a coal conservation board to advise the provincial Mineral Resources Minister and would permit the province to licence all private coal companies. The licencing would give the province more long-term control over coal mining developments. A study is now under way to evaluate the alternative uses for Saskatchewan's coal, and a more comprehensive statement on provincial coal policy is expected in 1978.

Nova Scotia also made an important provincial commitment to coal development in 1976. The government invited the coal industry to examine current information on coal resources within the province and to submit proposals for exploration and development. Nova Scotia is committed to coal for increased electrical generation and for expansion of its iron and steel industry, but may be constrained more by cost than market factors. The government plans to work closely with industry in the development of this basic sector of the provincial economy, but expects those companies which become involved in coal developments to have both the skill and financial capability to adequately complete the task.

National policy

Progress was also made towards the development of a national coal policy in 1976. As a result of meetings between the Honourable Alastair Gillespie, federal minister of Energy, Mines and Resources, and provincial ministers of mines, a consensus of support and willingness to work toward a new national policy was indicated by both producing and consuming provinces. Discussions on elements of a coal policy took place between federal and provincial officials throughout 1976. Critical elements singled out for special attention included a national inventory of coal resources; projections of future coal demand in both domestic and export markets; studies on the impact of transportation costs on coal marketing; research and development on the conversion of coal into synthetic gas; and an export policy providing Canada with the right of first refusal to ensure adequate supplies for domestic requirements. The officials felt that a national coal policy should help to determine the role that coal can, and should, play in meeting Canada's energy needs and in promoting Canada's industrial development.

COAL'S ROUTE TO CONSUMPTION



Production and mine developments

British Columbia. Although coal deposits occur in several areas of the province, all production currently comes from Crowsnest Coalfield in the southeast part of the province. British Columbia's three coal-producing operations and several potential mines are located in the Upper Jurassic and Lower Cretaceous coal formations of this field. In the northeast corner of the province Lower Cretaceous deposits of the Peace River Coalfield are the subject of several feasibility studies, while technological, engineering and economic studies concerning a proposed coal-fired thermal generating plant are under way on the Tertiary coal of the Hat Creek Coalfield in south-central British Columbia. Other major coal-bearing formations include the Groundhog Deposit and the Merritt, Similkameen, Cumberland and Nanaimo coalfields.

B.C.s largest operator for the last several years has been Kaiser Resources Ltd. While retaining this distinction in 1976, a weak coking coal market and a strike at its coal mining operations contributed to a 10 per cent reduction in Kaiser's output. The company's total 1976 production was 6.9 million tonnes, with 6.0 million tonnes coming from the largest single coal-mining operation in Canada, the Harmer Ridge surface mine; and 0.9 million tonnes from the underground Michel Colliery. Because of low productivity with conventional mining techniques, Kaiser developed Canada's first hydraulic mine at its Michel Colliery. This relatively new method of mining uses a high-pressure water jet to cut coal from the face and then hydraulically transports the coal to the surface by gravity or by mechanical pumps.

In 1976 Kaiser marketed 4.4 million tonnes of coal to Japan and smaller amounts to steel companies in Korea and Mexico. The shipments to Korea and Mexico represent new long-term contracts for 4.2 million tonnes and 690 000 tonnes, respectively. In its continuing efforts to diversify markets, Kaiser also sold trial cargoes in 1976 to two Brazilian steel mills and thermal coal to Denmark.

Mine developments during 1976 included the construction of underground dewatering and pumping stations and rock tunnels in Panel 6 of a new hydraulic mine which is to begin production in 1979. To the north and east of Fernie, feasibility and economic studies of the proposed new underground hydraulic mine and preparation plant at the Hosmer Wheeler site continued. A decision on development and production from this mine may be forthcoming in 1977 with potential markets likely to comprise Japanese and Latin American steel industries. Kaiser Resources Ltd., through its wholly-owned subsidiary Westshore Terminals Ltd., is also engaged in coal-handling operations at Roberts Bank, south of Vancouver. In 1976, 7.0 million tonnes of coal were shipped through this port. The possibility of expansion to handle increased coal movements has been raised, and initial studies related to an expansion are under way.

Fording Coal Limited was the second-largest producer in B.C. in 1976, with an output of 1.6 million tonnes of clean coal, down considerably from its 1975 output. The Fording operations are carried on near the B.C.-Alberta border about 55 kilometres north of Sparwood. Production was down in 1976 because of the weak coal markets in Japan and a four-month miners' strike. All Fording's medium volatile bituminous production was marketed to Japan under long-term contracts. During 1976 evaluation of a potential hydraulic mine at Eagle Mountain continued and further work is scheduled for 1977. Modifications to improve coal recovery were under way at Fording's wash plant during 1976.

The open-pit mine of Byron Creek Collieries Limited near Corbin on the British Columbia-Alberta border was the other significant producing mine in B.C. Output in 1976 was 350 000 tonnes of raw coal for power generating, coking and general industrial markets. In September it was announced that Byron Creek's contract with Ontario Hydro had been increased from 225 000 tonnes to 450 000 tonnes. Other contracts include a 13-year agreement with Sumitomo Metal Industries Ltd. of Japan for form coke, and contracts with industrial users in Manitoba and B.C. To accommodate increased production capacity, Byron Creek is anticipating completion of a rail spur to the C.P.R. mainline at McGillivray during 1977, and construction of a preparation plant in 1977-78.

Exploration work and feasibility studies continued on several fronts in British Columbia in 1976. In the southeast corner of the province major studies were under way on the Hosmer-Wheeler, Sage Creek, Line Creek and Elco properties. As mentioned above, Kaiser Resources Ltd. and its Japanese partners continued their studies on the Hosmer-Wheeler project and a decision on this property may be made in 1977.

Work continued in 1976 on a feasibility study of the Sage Creek coal property. This development is located in the Flathead River Valley in the southeast corner of B.C. and is owned by Rio Algom Limited and Pan Ocean Oil Ltd. A feasibility study was also under way by Crows Nest Industries Limited and Mitsui and Co. Ltd. of Japan on the Line Creek property in 1976. This property is situated about 25 kilometres north of Sparwood. Based on known reserves production from this property could average 1.8 million tonnes a year for 20 years.

During 1976 work continued on the evaluation of the Elk River coking coal deposit north of the existing Fording Coal Limited mine. The Elk River deposit is owned by Elco Mining Limited, which is in turn owned by The Steel Company of Canada, Limited, Home Oil Company Limited, Scurry-Rainbow Oil Limited, and Elco (a group of six European steel companies). In 1976 a prospectus was submitted to the B.C. Environmental and Land Use Committee as the first step towards going through the four-stage assessment procedure outlined in B.C.'s *Guidelines for Coal Development*. The equity position of The Steel Company of Canada in this venture demonstrates the potential for western coking coal properties seen by some sectors of the Canadian steel industry. FIRA approval for this development was granted in 1976.

In the northeast corner of B.C. exploration work and feasibility studies continued on several properties in the Peace River Coalfield. During 1976 Brascan Resources Limited decided not to exercise its option on the Sukunka coal project. However, work at this property continued with Brameda Resources Limited retaining majority control. Brameda began discussions late in 1976 with the intention of selling their interest in this project. Brameda Resources Limited and Teck Corporation Limited also continued work at their adjoining Bullmoose property.

To the south of the Sukunka-Bullmoose area work was under way on the Quintette project, which involved the Babcock and Wolverine coal areas. Controlling companies involved in this project were Denison Mines Limited, Mitsui Mining Co., Ltd. and Tokyo Boeki Ltd. Depending on market conditions, provincial government regulations, provision of infrastructure and other factors, production could began in the early 1980s and full production from both locations could reach 5 million tonnes by the middle or late 1980s.

Exploration work and feasibility studies continued on the Carbon Creek deposit of Utah Mines Ltd. and the property of Cinnabar Peak Mines Ltd., north of the Sukunka-Quintette deposits. To the south of all these properties, an exploration program was carried out on the Saxon property under an agreement between Denison Mines Limited and European and Japanese interests.

The other major work underway in B.C. centred on the thermal coal deposits at Hat Creek about 200 kilometres northeast of Vancouver. Engineering, environmental and economic assessments were under way in 1976 on these large coal deposits. The resources are estimated to be adequate to supply one — and possibly two — 2 000 megawatt thermal electric generating plants for 30 plus years, but more study will be required prior to any decision.

Alberta. Coal deposits underlie much of Alberta in both the Plains and Foothills Regions. In the Plains Region relatively flat seams of subbituminous coal of Upper Cretaceous age are mined for thermal power generation while bituminous coals from the Outer and Inner Foothills Belts are mined for coking or for use in the generation of electricity. In 1976 production in Alberta totalled 11.0 million tonnes, of which 6.4 million tonnes was subbituminous and 4.6 million tonnes bituminous, (including small amounts of semi-anthracite).

With a raw coal output of 3.2 million tonnes, McIntyre Mines Limited was the largest of the four coking-coal operations in Alberta. Clean coal output reached 1.9 million tonnes, while middlings output (sold to Alberta Power Limited) amounted to 580 000 tonnes. McIntyre developed two new underground mines for production in 1976, the No. 2 R-4 Mine in the Reiff Terrace area, and the No. 2-10 Mine near the existing No. 2-4 Mine. Development work was completed in two other underground mines, No. 2 A-4 and 2-11; while depillaring operations were under way in No. 2-4 Mine. Total production from surface mines increased in 1976 to 2.1 million tonnes. The No. 8 Surface Mine was mined out, with over 836 000 tonnes extracted, and output from the No. 9 Surface Mine totalled 1.3 million tonnes. Other developments at Smoky River included the construction of a tailings dewatering plant and the replacement of mining machinery and equipment, including four continuous miners.

The Luscar Ltd., Cardinal River Mine No. 1768 operation was the second largest coking-coal producer in Alberta. In 1976, 1.7 million tonnes of clean coal were produced from these open-pit operations southwest of Hinton. During the year development of two new pits began near existing operations. All the output

Table 5. Producers' disposition of Canadian coal[1], 1976

Destination	Originating Province: Nova Scotia	New Brunswick	Saskatchewan	Alberta	British Columbia and Yukon	Canada
	(tonnes)					
Railways in Canada	71	—	58 135	111	—	58 317
Newfoundland	1 149	—	—	—	—	1 149
Prince Edward Island	13 978	—	—	—	—	13 978
Nova Scotia	1 004 542	10 112	—	35 839	—	1 050 493
New Brunswick	50 292	206 352	—	—	—	256 644
Quebec	51 391	79 798	—	—	—	131 189
Ontario	79 942	—	40 534	249 845	180 302	550 623
Manitoba	—	—	1 263 555	18 752	51 168	1 333 475
Saskatchewan	—	—	3 310 406	461 003	2 926	3 774 335
Alberta	—	—	—	5 842 466	—	5 842 466
British Columbia	—	—	—	10 682	233 468	244 150
Total Canada	1 201 365	296 262	4 672 630	6 618 698	467 864	13 256 819
United States	—	86	2 370	195	321	2 972
Japan	—	—	—	3 823 034	6 368 883	10 191 917
Other	796 583	—	—	40 234	676 531	1 513 348
Total Shipments	1 997 948	296 348	4 675 000	10 482 161	7 513 599	24 965 056

Source: Statistics Canada.
[1]Saleable coal (raw coal, clean coal and middling sales).
— Nil.

Table 6. Canada, exports and imports of coal, 1975-76

	1975		1976ᵖ	
	(tonnes)	($)	(tonnes)	($)
Exports				
Japan	10 764 652	455 001 000	10 600 604	519 566 000
South Korea	—	—	348 075	18 143 000
West Germany	91 591	1 989 000	286 850	7 110 000
Denmark	136 551	2 519 000	274 836	5 537 000
France	267 464	4 624 000	81 353	1 550 000
Sweden	—	—	54 328	1 200 000
Mexico	—	—	50 436	2 704 000
United States	110 958	3 582 000	20 778	373 000
United Kingdom	322 970	10 157 000	19 981	526 000
Belgium and Luxembourg	—	—	18 039	400 000
Netherlands	—	—	6 007	200 000
Ste. Pierre and Miquelon	470	28 000	656	19 000
Total	11 694 656	477 900 000	11 761 943	557 328 000
Imports (for consumption)				
Anthracite				
United Kingdom	3 248	192 000	—	—
United States	288 762	15 242 000	213 381	10 839 000
Total Anthracite	292 010	15 434 000	213 381	10 839 000
Bituminous				
France	27	3 000	—	—
Poland	30 563	1 997 000	—	—
United States	14 932 305	557 382 000	14 371 638	532 008 000
Total Bituminous	14 962 895	559 382 000	14 371 638	532 008 000
Total Imports	15 254 905	574 816 000	14 585 019	542 847 000

Source: Statistics Canada.
ᵖPreliminary; — Nil.

from the Cardinal River operations was marketed to Japan under long-term contract.

Coleman Collieries Limited produced a total of 1.4 million tonnes of raw coal in 1976, mostly from two open-pit mines at Tent Mountain on the B.C.-Alberta border. Output from Tent Mountain approached 1.3 million tonnes in 1976, while the Vicary Creek underground mine produced 165 000 tonnes. Coleman continued work on a feasibility study of its Tent Mountain No. 5 Mine, which is to supplement dwindling capacity at existing mines. The new operation has reserves estimated at 27 million tonnes, all mineable by opencut methods. Coleman currently supplies about 900 000 tonnes of coal to Japan annually under a long-term contract.

The Canmore Mines, Limited produced 91 000 tonnes of semi-anthracite coal in 1976, in spite of termination of its surface operations. The Canmore Mines Limited is the only producer of semi-anthracite coal in Canada and markets the bulk of its output to Japan.

Subbituminous coal from the Plains Region of Alberta is generally consumed at mine mouth or nearby thermal power stations. Much of the subbituminous coal produced in Alberta is consumed by Calgary Power Ltd.'s Sundance and Wabamun power stations and by the Battle River power station of Alberta Power Limited. Production at the Calgary Power Ltd. Highvale Mine reached 2.6 million tonnes in 1976. A new dragline and other new mining equipment helped increase output by 40 per cent over 1975, making this the largest producing mine in Alberta. Within the next few years the Highvale Mine is expected to produce about 8.0 million tonnes annually which could make it the largest mine in Canada. Production at the Whitewood Mine, also owned by Calgary Power Ltd., declined by 10 per cent in 1976 to 2.1 million tonnes.

In the Forestburg — Halkirk region, the Manalta Coal Ltd. Vesta Mine and the Forestburg Collieries Limited, Diplomat Mine produced coal for the Battle

Table 7. Canada, supply and demand of coal, 1965 and 1975

	1965	1975[p]		1965	1975[p]
	(tonnes)			(tonnes)	
Supply			**Demand**		
Production	10 432 687	25 258 956	Residential	1 870 784	–
Land imports	14 759 654	15 819 893	Railways	202 302	63 793
Total inventory change	+642 557	+3 257 540	Ships bunkers	311 272	17 101
Total supply	24 549 784	37 821 309	Government and institutional	166 015	–
Demand			Subtotal	2 550 373	80 894
Domestic sales					
Electric utilities	7 005 021	16 570 669	Coal mine and local use	727 390	223 053
			Unaccounted for coal	+774 600	+722 363
Mining and Manufacturing	6 884 044	1 088 531	Total domestic demand	23 437 580	26 126 654
Coke-making	5 496 152	7 441 144	**Exports**	1 112 203	11 694 655
Subtotal	19 385 217	25 100 344	Total demand	24 549 783	37 821 309

Source: Statistics Canada.
– Nil

River Power station and other consumers. Production at the Vesta Mine was 533 000 tonnes in 1976, up slightly from 1975, while output at the Diplomat Mine declined by 23 per cent to 733 000 tonnes, reflecting the termination of a contract to supply coal to Saskatchewan Power Corporation's Queen Elizabeth generating station in Saskatoon.

Production from Manalta Coal Ltd.'s Roselyn Mine near Sheerness increased to about 362 000 tonnes, most of which went to the Queen Elizabeth generating station of Saskatchewan Power Corporation in Saskatoon.

Exploration and other activities remained at a low level in Alberta in 1976 compared to earlier years. Release of its coal policy ended a ban on new mine development but did not result in significant expansion of activities. However, work progressed on two properties that had previously been held in abeyance pending release of the coal policy. The Gregg River Resources Ltd. project near Hinton, Alberta was given an industrial development permit by the provincial cabinet subject to provisions contained in the new coal policy. Development of this 1.4-1.8-million-tonne-a-year mine must still await a firm contract with Japanese customers. The other major project to receive provincial cabinet approval in 1977 was the Coal Valley project of Luscar Sterco Ltd., a subsidiary of Luscar Ltd. Beginning in 1978 this mine will supply 1.8 million tonnes of coal to Ontario Hydro under a 15-year contract. The mine is about 65 kilometres southwest of Edson and will not require significant new infrastructure since it will utilize rail facilities serving the Cardinal River mine and accomodate most workers in Edson. Other developments in 1976 included a submission for a permit to develop a new mine near the existing Forestburg mine. To be called the Forestburg Collieries Limited South, this mine would produce coal for the Battle River power station. Preliminary approval was also given to submit an application for a permit and license for a new mine at Sheerness, near Hanna, in the east-central part of the province. This mine would provide coal for a proposed new thermal electric generating plant that would be built in the early 1980s.

Saskatchewan. The major coal deposits of Saskatchewan are concentrated in the southern part of the province, although deposits also occur in central Saskatchewan. The Paleocene lignitic deposits of southern Saskatchewan occur in four major basins: Estevan, Willowbunch, Wood Mountain and Cypress, and have been delineated and evaluated through a joint federal-provincial coal evaluation program. Very little is known of the deposits near Lac La Ronge in central Saskatchewan. All current production comes from the Estevan-Bienfait region and in 1976 totalled 4.7 million tonnes, up from 3.5 million tonnes in 1975. Most of the output was consumed by the Saskatchewan Power Corporation (SPC) in its lignite-fired power stations at Boundary Dam and Estevan. Two of the major producing mines, the Manitoba and Saskatchewan Coal Company (Limited) Boundary Dam Mine, and the Utility Mine of Manalta Coal Ltd., produced coal exclusively for the SPC Boundry Dam

Table 8. Provincial coal royalties in Canada

Province	Effective Date	Terms
Nova Scotia	1975	$0.28 a tonne
New Brunswick	1968	$0.15 a tonne
Saskatchewan	1957	$0.06 a tonne
Alberta	July 1/76	Royalty is determined by a formula based on annual costs of production, annual gross revenue, and allowed cumulative investment, including working capital.
British Columbia	1975	$1.48 tonne, metallurgical grade $0.74 tonne, thermal grade
Yukon and Northwest Territories	1965	lease: $0.11 tonne permit: $0.28 tonne

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

generating station. Output from these mines reached 1.5 and 1.2 million tonnes, respectively. The Klimax Mine of Manalta Coal Ltd. and the Bienfait Mine of the Manitoba and Saskatchewan Coal Company (Limited) produced 1.1 million and 763 000 tonnes of coal for thermal power generation in Saskatchewan and Manitoba, and for industrial purposes. A fifth mine which came on stream in 1976, will become a significant producer in the next few years. The Souris Valley Mine of Saskatchewan Power Corporation, situated south of Estevan, produced 19 000 tonnes by surface methods. The stripping of overburden began early in 1976 with a rebuilt dragline and deliveries to the Boundary Dam Power Station began in November. Eventual output from this mine is scheduled to reach 318 000 tonnes. Short-term markets for Saskatchewan coal are expanding in Manitoba as low water conditions reduce electricity output from hydro sources. Coal consumption in 1976 increased almost three-fold in Manitoba to 990 000 tonnes and may be even higher in 1977. Long-term thermal markets within and outside of Saskatchewan are also expanding. Beginning in 1980 coal from Manitoba and Saskatchewan Coal Co.'s Bienfait Mine will move to an Ontario Hydro generating station at Thunder Bay. Eventual movements will total 0.9 million tonnes and the work necessary at the mine to increase production capacity is under way.

New Brunswick. All of the coal produced in New Brunswick in 1976 came from the Grand Lake coal basin in the Minto-Chipman area of eastern New Brunswick. The coal, of high-volatile bituminous rank, is produced by a provincial Crown company, N.B. Coal Limited. Most of the coal is marketed to the New Brunswick Electric Power Commission for use in the Grand Lake and Chatham thermal power stations. Other markets include industrial consumers and local domestic markets.

In 1976 raw coal production totalled 430 000 tonnes, up slightly from 418 000 tonnes in 1975. In spite of reduced production, stockpiles increased as new markets failed to develop in the face of competition from oil and other coal. Markets for N.B. coal in Quebec include industrial plants at Timiskaming, Shawinigan and Villeneuve. During 1976 work progressed on a new operation in the Grand Lake area, a few kilometres from the existing power station, on the site of a mine that ceased operation in 1970. Estimated reserves of saleable coal are placed at 7.3 million tonnes, and initial annual output, using a new 65 cubic yard dragline, at 270 000 tonnes. Production is scheduled to begin in 1979 and output from this mine will eventually be consumed at both Grand Lake and the future Dalhousie power plant.

Nova Scotia. Nova Scotia's medium and high-volatile bituminous coal, Pennsylvanian in age, is found in, and off, Cape Breton Island and in the northern part of the mainland. Much of the coal contained in the productive Sydney Coalfield is located offshore, while coalfields on the west coast of Cape Breton Island lie both offshore and onshore. The mainland coalfields of Pictou, Springhill and Joggins have been mined extensively in the past but still contain mineable reserves.

Production of raw coal reached 2.3 million tonnes in 1976, up from the 1.8 million tonnes produced in 1975. The majority of this production came from the three mines of the Cape Breton Development Corporation (Devco): the Lingan Mine, No. 26 Colliery and the Prince Mine. During the year the Princess Colliery and the Bardswich and McNeil Pits at Point Aconi were phased out of production, but expansion of output from other mines more than made up for this lost output. Production of raw coal at the Lingan Mine expanded by over 20 per cent in 1976 to 1.2 million tonnes as a result of the addition of a third longwall face and new belt-haulage system. The opening of No. 12 N and No. 12 S walls enabled output at No. 26 Colliery to reach 808 000

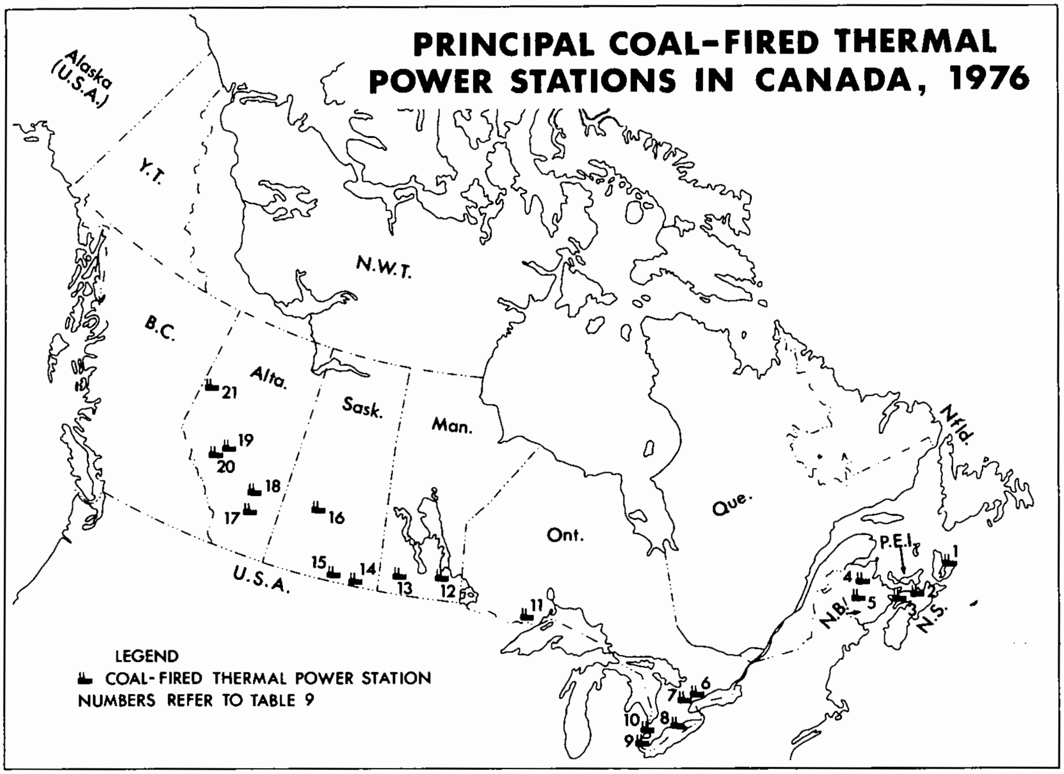


Table 9. Principal coal-fired thermal power stations in Canada, 1976

Utilities	Station	Total Station Capacity	Remarks
(numbers refer to map above)		(kilowatts)	
Nova Scotia			
1. Nova Scotia Power Corporation	Glace Bay	111 000	
2. Nova Scotia Power Corporation	Trenton	210 000	
3. Nova Scotia Power Corporation	Harrison Lake	25 000	
New Brunswick			
4. New Brunswick Electric Power Commission	Chatham	32 500	
5. New Brunswick Electric Power Commission	Grand Lake No. 1	13 750	
New Brunswick Electric Power Commission	Grand Lake No. 2	85 000	
Ontario			
6. Ontario Hydro	Richard L. Hearn	1 222 500	
7. Ontario Hydro	Lakeview	2 422 500	
8. Ontario Hydro	Nanticoke	3 022 500	Two 500 mW units to be added by 1978.

Table 9. (cont'd)

Utilities	Station	Total Station Capacity	Remarks
(numbers refer to map above)		(kilowatts)	
Ontario (cont'd)			
9. Ontario Hydro	J. Clark Keith	271 500	Station was closed down in early 1976 for modification and renovation; on stream in 1980.
10. Ontario Hydro	Lambton	2 022 500	
11. Ontario Hydro	Thunder Bay	128 300	Two 150 mW lignite-fired units to be added by 1980.
Manitoba			
12. Manitoba Hydro	Selkirk	155 800	
13. Manitoba Hydro	Brandon	237 000	
Saskatchewan			
14. Saskatchewan Power Corporation	Estevan	70 000	
15. Saskatchewan Power Corporation	Boundary Dam	582 000	300 mW-addition scheduled for 1977.
16. Saskatchewan Power Corporation	Queen Elizabeth	232 000	
Alberta			
17. Alberta Power Limited	Drumheller	15 000	
18. Alberta Power Limited	Battle River	362 000	One 375 mW-addition scheduled for 1979.
19. Calgary Power Ltd.	Wabamun	582 000	
20. Calgary Power Ltd.	Sundance	1 350 000	Two 375-mW units to be added by 1981.
21. Alberta Power Limited	H.R. Milner	150 000	Burns coal preparation plant by-products.

Source: Statistics Canada.

Table 10. Coal used by thermal power stations in Canada, by provinces, 1961-76

	Nova Scotia	New Brunswick	Ontario	Manitoba	Saskatchewan	Alberta	Total Canada
			(000 tonnes)				
1961	457	152	247	105	875	208	2 044
1962	467	110	1 354	101	1 024	323	3 379
1963	484	97	2 547	60	956	528	4 672
1964	530	222	2 795	132	1 006	999	5 684
1965	633	334	3 567	175	1 085	1 211	7 005
1966	799	294	3 500	79	1 116	1 360	7 148
1967	758	275	4 435	38	1 334	1 427	8 267
1968	646	240	5 523	179	1 354	2 128	10 070
1969	676	150	6 424	51	1 123	2 378	10 802
1970	548	113	7 696	503	1 969	2 951	13 780
1971	689	271	8 560	446	1 996	3 653	15 615
1972	663	281	7 599	410	2 145	4 113	15 211
1973	585	193	6 615	386	2 806	4 474	15 059
1974	606	292	6 721	132	2 902	4 771	15 424
1975	571	248	6 834	323	3 251	5 345	16 572
1976^p	726	208	7 446	990	3 537	5 995	18 902

Source: Statistics Canada.
^{p} Preliminary.

Thermal power industry

In 1976, some 18.9 million tonnes of coal were used for the generation of electricity in Canada, an increase of 14 per cent over 16.6 million tonnes in 1975. About 60 per cent of the coal used to generate electricity in Canada in 1976 came from Canadian mines with the rest imported from the United States. Three of the six provinces using coal (Alberta, Nova Scotia and New Brunswick) produced all their requirements from indigenous sources, while one province (Saskatchewan) produced most, but also imported some, of its requirements. Two other provinces (Ontario and Manitoba) purchased all requirements from outside their borders. Five of the six coal-consuming provinces are planning or building increased coal-fired capacity, and one province, British Columbia, is investigating the possibility of developing a large coal-fired thermal electric capability. Ontario, currently the largest thermal coal-consuming province, is in the process of developing new supply sources in western Canada, breaking its traditional reliance on United States coals.

During 1976 Ontario Hydro remained the largest coal-consuming utility in Canada, burning 7.4 million tonnes, while importing 6.9 million tonnes from the Appalachian region of United States. Ontario Hydro has more than 9.3 million tonnes per year of United States coal under long-term contract and will have a further 2.7 million tonnes per year available by 1980, supplied from the new Cumberland Coal Mines in Pennsylvania jointly owned by Ontario Hydro and the United States Steel Corporation.

Work continued on the upgrading and modifications of the transportation system that will lead to the first major movement of western Canadian coal to central Canada. This system, which stretches from Alberta and B.C. to Thunder Bay and central Ontario, will include upgraded track, new equipment (including 36 new locomotives and 800 new coal cars), a terminal at Thunder Bay (with an initial throughput capacity of 2.7 million tonnes) and lake freighters. Total cost of the system is estimated at $350 million.

Preparatory work is under way at the Luscar Sterco Ltd. mine in Alberta, the Byron Creek Collieries Limited in British Columbia and the Manitoba and Saskatchewan Bienfait Mine in Saskatchewan to develop an annual production capacity of about 3.5 million tonnes of bituminous and lignite coals by the early 1980s. Beginning in 1978 bituminous coal from Alberta and British Columbia will be blended with United States coal and burned at Ontario Hydro's Nanticoke generating station. The lignite coal from Saskatchewan will be burned at the Thunder Bay

Table 12. Canada, coke production and trade, 1975-76

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Production				
Ontario	4 531 514	*	4 751 399	*
Other provinces	746 322	*	537 785	*
Total	5 277 836	*	5 289 184	*
Imports				
United States	508 653	47 311 000	271 723	25 665 000
West Germany	37 803	4 815 000	10 174	1 136 000
France	—	—	5 348	506 000
United Kingdom	—	—	4	. . .
Total	546 456	52 126 000	287 249	27 307 000
Exports				
United States	65 051	2 666 000	78 356	4 452 000
West Germany	—	—	26 894	928 000
Netherlands	15 639	532 000	64 644	2 344 000
Japan	—	—	—	—
Spain	15 391	442 000	—	—
Total	96 081	3 640 000	169 894	7 724 000

Source: Statistics Canada.
*Practically all coke production is used by producers in the iron and steel industry and is not given a dollar value.
^{p}Preliminary; — Nil; . . . Insignificant.

thermal station in 1980. The decision by Ontario Hydro to burn Canadian coal was the result of a major change in purchasing philosophy to acquire, transport and blend initially higher-cost Canadian coal. While the initial per unit cost of western Canadian coal will exceed that of Appalachian coal, the benefits of low sulphur levels, diversification of supply sources, and reduction of uncertainty about coal prices make this domestic coal and the development of the required transportation system attractive.

Work on new coal-fired units progressed at two locations in Ontario in 1976. At Thunder Bay work on a two-unit 300-megawatt extension to the existing coal-fired station continued. Completion is scheduled for 1980, when total generating capacity at Thunder Bay will be 400 megawatts.

Work on the last three coal burning units at Nanticoke continued with completion of the sixth unit scheduled for 1977 and the seventh and eighth units for 1978. In December cracked boiler rods at Nanticoke created problems with several units during a peak demand period. Repairs are expected to be completed during 1977.

The J. Clark Keith coal-fired generating station at Windsor was mothballed in 1976 for modification to meet environmental regulations. Redesign and other necessary work is expected to be completed in early 1980.

Work on all existing and committed projects will require Ontario Hydro coal consumption to increase to between 14 and 16 million tonnes in the 1980s.

The year 1976 was another period of growth and expansion for the thermal coal industry in Alberta. Consumption of coal for the generation of electricity reached 6.0 million tonnes in 1976, up 12 per cent from 1975. The major development in the thermal power sector was the July announcement by the Alberta government that the application of Calgary Power Ltd. and Canpac Minerals Limited to develop the Camrose-Ryley coal mine and coal-fired power station project would not receive government approval. The government stated, in light of its new coal policy, that the project would disturb too much prime agricultural land compared to potential alternatives. The project, 55 kilometres southeast of Edmonton, was to have included six 375-megawatt units and would have consumed 275 million tonnes of subbituminous coal over 35 years. Existing and newly planned facilities will now have to provide the power that was to have come from this development.

A partial replacement for the power that would have come from the Camrose-Ryley project may be provided by the construction of a new coal-fired generating station by Calgary Power Ltd. To be known as South Sundance, this development, a few kilometres from the existing Sundance station, could be generating electricity by 1982. Initial development would involve two 375-megawatt units, with the possibility of two more units to follow. An application for this project is before the Alberta Energy Resources Conservation Board.

During 1976 Calgary Power Ltd. completed construction of a fourth unit at the Sundance generating station, raising capacity to 1 350 megawatts. Work on the fifth and sixth units is under way with completion scheduled for 1978 and 1980. Total generating capacity will then be 2 100 megawatts, requiring about 8.0 million tonnes of coal per annum.

Alberta Power Limited, a subsidiary of Canadian Utilities Limited, is the other major utility producing electricity from coal in Alberta. The Battle River generating station near Forestburg is the largest of

Table 13. Canada, coke production and trade, 1966-76

	Production		Imports		Exports	
	Coal Coke	Petroleum Coke	Coal Coke	Petroleum Coke	Coal Coke	Petroleum Coke
			(tonnes)			
1966	4 015 246	208 760	530 671	452 825	70 717	8 771
1967	4 019 100	206 735	351 125	513 318	59 232	16 911
1968	4 817 842	216 455	231 700	509 300	130 427	5 207
1969	4 537 988	210 176	254 833	638 279	247 659	2 364
1970	5 142 122	188 376	358 295	706 769	248 469	48 343
1971	4 631 897	187 278	586 430	665 774	288 272	11 171
1972	4 675 866	242 370	481 816	555 710	238 478	881
1973	5 369 861	286 530	357 815	637 664	367 916	1 966
1974	5 443 427	274 412	509 058	746 033	260 892	24 940
1975	5 277 837	270 685	546 456	572 557	96 081	161 576
1976[p]	5 289 185	678 432	287 249	591 859	169 895	136 970

Source: Statistics Canada.
[p] Preliminary.

Alberta Power Limited's three coal-fired generating stations. During 1976 work began on the installation of a 375-megawatt addition to this generating station, estimated to cost $236 million. Construction of the turbine generator is expected to start in 1977 and commissioning is planned for 1981.

Cancellation of the Camrose-Ryley project may accelerate Alberta Power's development plans for a new thermal-generating station at Sheerness, about 25 kilometres southeast of Hanna, Alberta. Initial application papers have been filed for the generating station based on the adjacent coal deposits. Two 375-megawatt units are planned, with commissioning of the first unit slated for the early 1980s. Actual timing will depend on both the demand for power and the licencing procedures. The H.R. Milner generating station, which supplies power to the coal mining town of Grande Cache and the surrounding area, is the other major coal-fired unit of Alberta Power Limited. This plant burns byproducts from the preparation plant of McIntyre Mines Limited.

In Saskatchewan work continued on two projects that will add 600 megawatts to the 884 megawatts of electricity now generated from coal. Construction continued on the sixth unit at the Boundary Dam Station of Saskatchewan Power Corporation. By year-end, work on the steam turbo generator and boiler was 75 per cent complete, with operation scheduled for the fall of 1977. This unit will add 300 megawatts to the present 582 megawatts generated at Boundary Dam and will be the final addition to the station. Work also continued on the new coal-fired Poplar River Power Station being constructed near the town of Coronach, 160 kilometres south of Moose Jaw. Commissioning of the first 300-megawatt unit is scheduled for 1979, with a second 300-megawatt unit planned for 1982.

Saskatchewan Power Corporation is working on the development of a new strip mine in the Coronach region to supply this station, with initial stripping scheduled to begin during the summer of 1978.

During 1976 Saskatchewan imported 461 000 tonnes of Alberta subbituminous coal for the Queen Elizabeth Power Station in Saskatoon, and exported 1.3 million tonnes of lignite coal to Manitoba. Imports and exports are expected to continue at about the same levels in 1977.

The amount of coal consumed in Manitoba to generate electricity increased dramatically to 990 000 tonnes in 1976. This represented a 206 per cent increase over the 1975 level of 323 000 tonnes. Low precipitation and subsequent low water conditions reduced hydro potential, prompting increased use of coal. Unusually high consumption of coal called for production of base load power from the Brandon and Selkirk thermal stations, traditionally used for peaking purposes only. Return of normal precipitation levels will reduce coal consumption to about 300 000 tonnes.

The New Brunswick Electric Power Commission currently has three stations capable of using coal to generate electricity. The Chatham and No. 1 and No. 2 Grand Lake stations have a generating capacity of 131 megawatts and in 1976 burned 208 000 tonnes of high-volatile bituminous coal from the Minto coalfields of N.B. Coal Limited. Coal consumption for the generation of power in New Brunswick has declined over the last three years, but is forecast to increase with the completion of the new Dalhousie generating plant. This 200-megawatt, dual-fired unit will have the capacity to burn either coal or oil and would require more than 270 000 tonnes of coal per annum if completely fired with coal. Work is under way by N.B. Coal Limited to

Table 14. World coal production

	1971	1972	1973	1974	1975[p]
			(000 tonnes)		
North America	521 229	562 182	561 552	571 486	611 085
South America	7 286	7 789	7 074	8 159	8 283
Europe	1 645 081	1 625 037	1 646 090	1 651 315	1 710 472
Africa	61 531	61 748	66 043	69 550	72 911
Asia	504 644	511 762	538 667	567 489	600 310
Oceania	74 509	85 567	87 797	92 986	97 683
World					
Lignite (estimate)	799 646	804 525[r]	819 437[r]	834 152[r]	860 593[e]
Bituminous and anthracite (by subtraction)	2 014 634	2 049 560	2 087 786	2 126 833	2 240 151
Total, all types	2 814 280	2 854 085[r]	2 907 223[r]	2 960 985[r]	3 100 744[e]

Source: U.S. Bureau of Mines.
[p]Preliminary; [r]Revised; [e]Estimated.

develop a new coal-mining operation near Grand Lake to partially fulfil the requirements of this new unit. Coal output from existing operations will also fuel this plant. While existing and planned facilities will satisfy New Brunswick's energy needs into the early 1980s, further use of native coal, possible use of peat and other fuels is being evaluated to meet energy needs in the mid- and late-1980s.

During 1976 the Nova Scotia Power Corporation consumed 726 000 tonnes of thermal coal at its three coal-fired stations, representing a 27 per cent increase over 1975 consumption levels and indicating the importance placed on this indigenous fuel by Nova Scotia. In mid-year the Nova Scotia Power Corporation and the Cape Breton Development Corporation completed an agreement that provided for the development of sufficient mine capacity to supply a new coal-fired power station at Lingan. The first 150-megawatt unit at Lingan is scheduled to be operational by 1979 and the second unit by 1981. Decisions on the third and fourth unit could bring generating capacity to 600 megawatts in the mid-1980s. With each 150-megawatt unit requiring 350 000 tonnes per annum, provincial demand for thermal coal could exceed 2 million tonnes per year by 1985. Demand could expand even more if experiments on burning an oil-coal slurry mix in previously oil-fueled plants prove successful.

Coke industry

In 1976, 7.4 million tonnes of bituminous coking coal were carbonized to produce 5.3 million tonnes of coke. Both coal and coke figures were basically unchanged from 1975. The majority of the coking coal imported into Canada was charged to the coke ovens of the three Ontario iron and steel companies and to the Sydney Steel Corporation in Nova Scotia.

Canada imported 6.6 million tonnes, or 89 per cent, of the bituminous coal used to produce coke in 1976. The remainder came from Nova Scotian and western Canadian mines. Long-term contracts, blending practices, equity holdings in coal mines in the United States and geographical separation of producing and consuming areas has in the past restricted the use of western and eastern Canadian bituminous coals in Ontario. However, availability of good quality coking coals; a desire to diversify supply sources; concern over long-term trends in pricing; development of a coal transfer facility at Thunder Bay and Nova Scotia's increased production capability have helped to make both eastern and western Canadian coking coals more attractive in recent years. Thus, while the United States will remain the major source of coking coal in the foreseeable future, Canada's coal reserves will assume increasing importance.

The majority of the coking coal purchased from the United States came from mines which were captive to, or which had long-term contracts with, Canadian importers. All of the U.S. coal imported to Canada came from the Appalachian Region and most was imported via the Great Lakes, except for 44 000 tonnes delivered to the Sydney Steel Corporation in Nova Scotia. The weak market for coking coals in the United States had little effect on the price paid for imported coal because the majority of Canadian imports were under long-term contract.

Approximately 90 per cent of the coke produced in Canada was charged to blast furnaces. Of the remaining coke output: 456 000 tonnes were sold for industrial purposes; 26 000 tonnes for other domestic uses; 84 000 tonnes for export; 6 000 tonnes for fuel and 17 000 tonnes for other uses associated with blast furnaces.

The 170 000 tonnes of coke exported in 1976 represented a 77 per cent increase over the 96 000 tonnes exported in 1975. Imports of coke totalled 287 000 tonnes in 1976, down from 547 000 tonnes in 1975. Total value of imports and exports was $37.3 million and $7.7 million respectively.

In 1976 an average of 1.43 tonnes of coking coal was required to produce a tonne of coke in Canada. The coke rate, the amount of coke consumed per tonne of pig iron produced in blast furnaces, was approximately 510 kilograms, down slightly from 513 in 1975. Based on these two factors it is estimated that, in 1976, about 760 kilograms (0.76 tonne) of coking coal was required per tonne of basic pig iron produced in Canada.

The Algoma Steel Corporation, Limited (Algoma) of Sault Ste. Marie produced 1.4 million tonnes of coke from 2.2 million tonnes of coking coal in 1976. The majority of Algoma's coking coal was obtained from its Cannelton Industries, Inc. subsidiary in the United States, although some coal was purchased on the open market. During the year Algoma continued to investigate potential coking coal properties in the United States but reached no decision on new mining investments. At Sault Ste. Marie, the new No. 9 Battery was shut down with technical problems after a short period of operation while work on the new No. 10 Battery, originally scheduled for completion in 1979, was deferred.

The Steel Company of Canada, Limited (Stelco) at Hamilton produced 2.0 million tonnes of coke in 1976 and purchased 3.0 million tonnes of coking coal. All but 165 000 tonnes of this coal was imported from the United States. During 1976 Stelco received 74 000 tonnes of coal from the Cape Breton Development Corporation in the first of a series of shipments that will bring 2.3 million tonnes of bituminous coking coal to its Hamilton operations over five years. Stelco also received 90 000 tonnes from McIntyre Mines Limited in what have become regular purchases from this western Canadian producer. The SL/RN kiln at Stelco's Griffith iron ore mine in the Red Lake district of northwestern Ontario was in its second year of operation in 1976. Total output was 70 000 tonnes, up from the 1975 output of 15 000 tonnes. Ultimate design capacity of this plant is 318 000 tonnes. Construction of Stelco's new Nanticoke iron and steel facility continued during 1976, with initial production now scheduled for 1980.

Dominion Foundries and Steel, Limited (Dofasco) of Hamilton produced 1.2 million tonnes of coke in 1976. Dofasco, like Algoma and Stelco, purchased the majority of its coal from the United States, where it has captive mines and long-term contracts. Like Stelco, Dofasco purchased coal from western Canada in 1976, obtaining 49 000 tonnes from McIntyre Mines Limited. This low-volatile coal was moved to Vancouver by rail and then by freighter through the Panama Canal and the St. Lawrence Seaway to Hamilton. Construction of Dofasco's No. 6 Battery continued during 1976, with start-up now scheduled for 1978. Output from the thirty five 6-metre ovens of this battery will reach over 400 000 tonnes of furnace coke at full capacity. Work on a new byproduct plant to complement the new coke oven battery was under way during 1976. Completion of this plant is also scheduled for 1978.

Sydney Steel Corporation of Sydney, Nova Scotia (Sysco) produced a total of 251 000 tonnes of coke in 1976, down 36 per cent from the 1976 output of 390 000 tonnes. Total coke output was divided between 233 000 tonnes of furnace coke, 6 000 tonnes of pea coke and 12 000 tonnes of breeze coke. Coal input in 1976 was 362 000 tonnes, of which 76 000 tonnes were low-volatile coal and 285 000 tonnes high-volatile coal. All the low-volatile coal came from McIntyres Mines Limited while 241 000 tonnes of the high-volatile coal came from Nova Scotia and 44 000 tonnes from United States sources. The Cape Breton Development Corporation supplied the majority of the Nova Scotian coal. Sysco's No. 6 battery was closed down for part of 1976 and will reopen, depending on demand.

The Lasalle Coke Division of Gaz Métropolitain, inc. in Montreal produced 160 000 tonnes of coke in 1976 and imported 194 000 tonnes of coal from the United States. The majority of this coke was marketed to industrial firms in Canada for foundry use.

The Manitoba and Saskatchewan Coal Company (Limited) Char and Briquetting Division in Bienfait, Saskatchewan produced 51 000 tonnes of lignite char from 132 000 tonnes of lignite coal. During the year a used Salem Rotary Harth Calciner coke oven was installed at the Bienfait plant. Work on upgrading the Lurgi carbonizing ovens continued and will be completed in 1977. The Bienfait plant markets its char in both Canada and the United States for the manufacture of barbecue briquettes.

In 1976 the Kaiser Resources Ltd. coke plant at Natal, British Columbia produced 101 000 tonnes of coke from 162 000 tonnes of coal. Depressed market conditions and a two-month strike contributed to a decrease in production from the previous year. Kaiser markets its coke to the mining industry in British Columbia and the sugar beet industry in Alberta.

Cobalt

R. JOHNSON

In 1976 Canadian shipments of cobalt were 1 373 024 kilograms, compared with 1 354 213 kilograms in 1975. Cobalt is produced by two companies, Inco Limited and Falconbridge Nickel Mines Limited, as a byproduct of nickel-copper mining in Canada, and a third, Sherritt Gordon Mines Limited, recovers cobalt from imported nickel concentrates. These three companies accounted for more than 99 per cent of the cobalt produced in Canada. Because of the byproduct relationship with nickel, cobalt production in Canada is governed by the level of nickel production.

Cobalt was in short supply during 1976 as transportation problems early in the year disrupted shipments from Zaire, which produces 60 per cent of the world's cobalt; and Zambia, which produces about 7.5 per cent of the world's cobalt. While this problem was resolved by the end of the year, a reduction, and finally a stoppage, in releases from the strategic stockpile of the United States in 1976 placed further pressure on the market. Releases from the stockpile had supplied about 10 per cent of world demand in recent years. There were three increases in the price of cobalt metal during 1976.

Demand is expected to increase slightly in 1977. The market is expected to remain tight in 1977 and further price increases may occur. In the medium term, the supplies of cobalt would appear to be sufficient to meet demand when several projects commissioned in 1978 and 1979 come into full production. The adequacy of the transportation systems in central and southern Africa to move the necessary amounts of cobalt from Zaire is open to question and may be responsible for causing some future short-term shortages.

Canada

There are three mine producers of cobalt in Canada: Inco Limited, Falconbridge Nickel Mines Limited and Agnico-Eagle Mines Limited. Inco and Falconbridge recover cobalt as a byproduct of nickel-copper ores mined in the Sudbury area of Ontario and the Thompson area of Manitoba, while Agnico-Eagle recovers comparatively small amounts from its silver mining operations in the Cobalt area of Ontario. A fourth company, Sherritt Gordon Mines Limited, recovers cobalt from the refining of imported nickel concentrates.

Inco recovers cobalt and cobalt compounds both in Canada and abroad. In Canada, Inco recovers cobalt oxide and electrolytic cobalt at its refinery in Port Colborne, Ontario and cobalt oxide at its Thompson, Manitoba refinery. Inco's refinery complex in Clydach, Wales recovers cobalt from nickel matte produced in Canada, and also produces upgraded cobalt oxides and salts from cobalt oxide produced in Canada. Falconbridge recovers electrolytic cobalt at its refinery complex in Norway from nickel matte produced in Canada. Sherritt Gordon recovers cobalt metal powder from nickel end solutions at its hydrometallurgical refinery in Fort Saskatchewan, Alberta. Agnico-Eagle produces a cobalt-containing concentrate that is shipped to the newly-opened silver refinery of Canadian Smelting & Refining (1974) Limited.

Table 1. Deliveries of cobalt by major Canadian producers, 1974-76

	1974	1975	1976
	(000 kg Co)		
Inco	503	472	1 102
Falconbridge	1 119	619	943
Sherritt Gordon	138	148	285
Total	1 760	1 239	2 330

Source: Company annual reports.

Canadian shipments of cobalt in 1976 were 1 373 024 kilograms valued at $11.8 million, compared with 1 354 213 kilograms valued at $12.5 million in 1975. These production figures include only cobalt produced from Canadian mines and, therefore, exclude Sherritt

Gordon's production. Table 2 shows the deliveries of cobalt made by Inco, Falconbridge, and Sherritt Gordon, and bears witness to the good year enjoyed by these cobalt producers. Agnico-Eagle is a small producer. In 1976 production of cobalt was 4 076 kilograms in silver concentrates, compared to 21 988 kilograms in 1975.

The only domestic development of any significance during the year was the closure of Sherritt Gordon's Lynn Lake, Manitoba mine in June 1976. The Lynn Lake mine had produced as much as one-sixth of the cobalt recovered at Fort Saskatchewan; however, the mine had lost money in recent years and had been supplying a declining proportion of the feed to the refinery. Sherritt Gordon is now therefore wholly dependent on imported feed for its cobalt production.

Canadian consumption is well distributed over the various uses of cobalt. The major consumers of cobalt by use and by product consumed are:

	Form in which cobalt consumed
for alloying purposes	
Atlas Steels Division of Rio Algom Limited	(metal)
Canada Alloy Castings Ltd.	(metal)
Deloro Stellite Division of Canadian Oxygen Limited	(metal)
Black Clawson-Kennedy Ltd.	(metal)
as a colouring agent	
Consumers Glass Company, Limited	(oxide)
Domglas Ltd.	(oxide)

Table 2. Canada, cobalt production, trade and consumption, 1975-76

	1975		1976^p	
	(kg)	($)	(kg)	($)
Production[1] (all forms)				
Ontario	1 088 512	10 277 852	1 139 000	9 679 000
Manitoba	265 701	2 270 031	234 000	2 090 000
Total	1 354 213	12 547 883	1 373 000	11 769 000
Exports				
Cobalt Metal				
United States	393 180	3 353 000	508 048	4 644 000
South Africa	19 667	442 000	7 545	118 000
Sweden	5 270	107 000	2 232	35 000
France	7 983	75 000	—	—
United Kingdom	3 024	57 000	—	—
Finland	511	10 000	1 078	17 000
Japan	544	5 000	714	12 000
Other Countries	332	6 000	3 880	53 000
Total	430 511	4 055 000	523 497	4 879 000
Cobalt oxides and hydroxides[2]				
United Kingdom	560 731	2 836 000	461 167	3 048 000
Japan	—	—	10 161	78 000
Total	560 731	2 836 000	471 328	3 126 000
Consumption[3]				
Cobalt contained in:				
Cobalt metal	97 717	..	123 836	..
Cobalt oxide	17 883	..	28 527	..
Cobalt salts	7 402	..	8 129	..
Total	123 002	..	160 492	..

Source: Statistics Canada.
[1]Production (cobalt content) from domestic ores. [2]Gross weight. [3]Available data reported by consumers.
^{p}Preliminary; — Nil; .. Not available.

Medicine Hat Brick and Tile Company Limited	(oxide)
in the manufacture of cemented carbide cutting tools	
Canadian General Electric Company Limited	(metal)
Macro Division of Kennametal Inc.	(metal)
in permanent magnets	
Canadian General Electric Company Limited	(metal)
in the manufacture of cobalt salts, driers and frit	
The Canadian Salt Company Limited	(salts)
Domtar Chemicals Limited	(salts)
Dussek Brothers (Canada) Limited	(metal and oxide)
Ferro Industrial Products Limited	(oxide)
Nuodex Products of Canada Limited	(metal)
as a feed supplement	
Maritime Co-operative Services	(salts)

Canadian consumption of cobalt in metal, oxide and salts was 160 492 kilograms in 1976, compared with 123 002 kg in 1975 and 185 262 kg in 1974.

Minerals and occurrences

Cobalt minerals are distributed widely throughout the world, invariably associated with other metallic minerals such as nickel and copper. The minerals of cobalt can be classified into three broad groups: arsenides, sulphides and oxidized cobalt minerals. Although there are over 70 known or suspected minerals of cobalt, only a few are of economic importance. The most important economic minerals of cobalt are:

skutterdite, smaltite	$CoAs_3$
cobaltite	$CoAsS$
linneaite	Co_3S_4
carrollite	$CuCo_2S_4$
heterogenite	$CoO{\cdot}OH$

There is a distinct relationship between cobalt minerals and the other metallic minerals with which they occur. The principal sources of cobalt are the copper deposits of Zaire and Zambia. In Zaire the cobalt occurs as both sulphides and oxidized minerals in the copper deposits, which are also both sulphides and oxides. In Zambia the cobalt appears primarily as a sulphide. With the nickel ores of Canada, Finland and Australia, the cobalt is primarily in the form of arsenides. Similarly, in the Cobalt area of Ontario cobalt appears primarily as an arsenide or sulpharsenide.

Cobalt in 1976

World production of cobalt in 1976 was an estimated 24 800 tonnes*, a slight increase over 1975. However, because of shipping problems occasioned by political events in Africa, deliveries of cobalt from producers are estimated to be down in 1976 by as much as five thousand tonnes. The level of dealer and consumer stocks are also down because of the heavy demands placed on them by the lower deliveries from producers. Zaire is the dominant producer and future mine developments there are expected to reinforce that position.

Demand for cobalt improved over the relatively low levels of 1975. This increase in demand would, under normal circumstance, have been met easily by existing suppliers; however, two developments during the year led to a tight supply situation and three increases in price. The major problem in 1976 was a short-term disruption of shipments from Zaire and Zambia as a result of the troubled political situation in central Africa; the second concerned changes in the stockpile release policy of the General Services Administration (GSA) in the United States. The Interruption in shipments from Zaire and Zambia caused a short-term problem in the market while the reassessment of the U.S. stockpile position resulted first in the curtailment of releases and latterly in the stoppage of releases. In recent years, the General Services Administration stockpile had supplied about 10 per cent of the total world demand.

The initial bottleneck in shipments from Zaire and Zambia resulted from the closure of the Benguela Railway, which runs from the copper-cobalt producing area of Zaire (Shaba Province) to the port of Lobito on the Angolan coast. The railway, which was damaged during the Angolan civil, war had been the principal outlet for the copper and cobalt produced in Zaire and Zambia prior to 1976. As a result of the closure Zambia began shipping copper and cobalt by truck to Mombasa in Tanzania for export and Zaire began stockpiling its production until alternate transportation routes could be found.

By April alternate transportation routes for Zaire cobalt had not been found and its distributors had not received any shipments since the new year. As a result, customers were placed on allocation until such time as regular shipments could be resumed. The interruption of supplies from Zaire was felt most by the producers of cobalt-base superalloys. Most other cobalt produced, which is a byproduct of nickel production, not copper as is the case in Zaire and Zambia; contains too much nickel for use in the manufacture of cobalt-base superalloys. Further pressure was placed on the market when the GSA announced that stockpile releases of cobalt would be reduced from a maximum monthly offering of 1 million pounds to 700 000 pounds in April and 500 000 pounds thereafter, and that releases would be restricted to those for domestic use only. As a result

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 3. Canada, cobalt production, trade and consumption, 1965-76

	Production[1]	Exports		Imports		
		Cobalt Metal	Cobalt Oxides and Hydroxides	Cobalt Ores[2]	Cobalt Oxides[2]	Consumption[3]
	(kg)					
1965	1 654 856	132 536	641 470	..	..	166 031
1970	2 068 931	380 949	836 878	..	..	148 338
1974	1 563 568	479 376	673 494	..	..	185 442
1975	1 354 213	430 511	560 731	..	..	123 002
1976[p]	1 373 000	523 497	471 328	..	..	160 492

Source: Statistics Canada.
[1]Production from domestic ores, cobalt content. From 1967, production includes cobalt content of Inco and Falconbridge Nickel Mines Ltd. shipments to overseas refineries, but prior years exclude Inco shipments to United Kingdom. [2]Gross weight. [3]Consumption of cobalt in metal, oxides and salts.
[p] Preliminary; .. Not available.

of this situation, there was a 40-cent-a-pound increase in the price of cobalt metal.

By early summer there was a good deal of uncertainty in the market. The principal areas of concern were:

(1) the adequacy of the African transportation system;
(2) that the GSA was only authorized to continue releases until September; and
(3) expectations that, given the precarious African situation, the Federal Preparedness Agency, which was reviewing stockpile objectives at that time, would substantially increase the stockpile objective for cobalt and thereby substantially reduce the amount of cobalt available for release.

This uncertainty was one of the principal factors in sustaining cobalt demand.

By summer the supply situation had started to ease considerably as near-normal shipments were resumed from Zaire. An alternate transportation route had been established, with exports of Zaire copper and cobalt being routed down the interior of Africa and shipped from the port of East London in the Republic of South Africa. Zambian shipments were now being routed from Zambia to Dar Es Salam in Tanzania via the recently completed Tanzam Railway.

The Benguela railway had been repaired by this time but Angola did not give Zaire permission to use it because of Zaire's support of a different faction in the recent civil war and purported support of anti-government political factions in Angola. As a result, Zaire cobalt continued to move through the longer, slower route via East London in the Republic of South Africa. Another factor in deciding to continue to use the East London route in the medium-term was reports that one of the defeated factions in Angola's civil war was waging reasonably successful guerilla warfare in the vicinity of the rail line.

In September the United States Federal Preparedness Agency set a new strategic stockpile objective of 85.4 million pounds of cobalt compared with the former objective of 11.9 million pounds. Since current holdings were only 40.7 million pounds, releases were stopped immediately. This again stimulated the market and was the cause for a further 50-cent-a-pound increase in the price of cobalt by Zaire distributors late in the month.

In the late fall, shipments from Zaire continued to increase, distributor stocks had returned to near-normal levels by November and the allocation scheme was removed in December. Early in 1977, there was an outbreak of fighting in the Shaba between government forces and insurgents. Cobalt production is not believed to have been affected to any significant degree.

International developments

Botswana. The Selebi-Pickwi nickel-copper mine of Botswana RST Ltd. had improved operating results during 1976, and early in 1977 production reportedly reached 90 per cent of capacity. Rated annual capacity of the mine and smelter is about 40 000 tonnes of nickel-copper matte. There are also minor amounts of cobalt in the matte which is sent to AMAX Inc.'s refinery at Port Nickel, Louisiana for treatment. At rated capacity, the mine can produce some 75 tonnes of cobalt a year.

Zaire. While cobalt production from Zaire is estimated to be some 14 000 tonnes in 1976, actual shipments are believed to be in the area of 10 to 11 000 tonnes because of the transportation problems mentioned earlier.

Gecamines, the state-owned mining company, is continuing its expansion program. The next phase, which is scheduled for completion in 1978, involves the

Table 4. Estimated world production of recoverable cobalt, 1975-76

	1975	1976[e]
	(000 tonnes)	
Australia	0.4	0.7
Canada	1.4	1.4
Finland	0.8	0.9
Morocco	1.9	1.9
Zaire	14.2	14.0
Zambia	1.9	1.8
Other Market Economy Countries	0.6	0.8
Subtotal	21.2	21.5
Centrally-planned Economies	3.2	3.3
Total	24.4	24.8

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[e] Estimated.

development of two new mines and a refinery complex near Kolwezi that will have the capacity to produce some 4 000 tonnes of cobalt metal a year.

Work on the copper-cobalt mine and refinery complex of the Société Minière de Tenke-Fungurume was stopped in early 1976. Over $200 million had already been spent on developing the site when the stoppage was announced. Included in the plans for the project was a 6 000-tonne-a-year cobalt refinery. Work was halted because of escalating costs and the political uncertainties in central Africa. The project is basically dependent on copper and the partners estimate that a copper price of 90 to 95 cents a pound is necessary to make it viable. Two of the partners are working on a scaled-down proposal that would cut back the initially proposed capacity by about one-third. However, this alternative has not been regarded with much enthusiasm by the principals.

Rhodesia. Rio Tinto (Rhodesia) Ltd. announced plans to build a cobalt treatment plant that will recover cobalt from the residues of the Empress Nickel Mining Co. Ltd. No details on plant capacity were announced, but it is scheduled to be in production sometime in 1977.

India. Following a report prepared by Chemical and Metallurgical Design Company Private Limited, the Indian government has approved plans for the development of a nickel mine and refinery complex in the Sukinda area of Orissa. The project will include a cobalt plant capable of producing some 200 tonnes a year. A final feasibility study was being prepared by an Indian company and Japanese consultants. No completion date has been mentioned.

Philippines. Marinduque Mining and Industrial Corporation's nickel refinery on Nonoc Island continued to have start-up problems. The refinery, which was commissioned in 1974, increased its production in mid-1976 to about 70 per cent of rated capacity. In addition to nickel, the plant also produces a mixed nickel-cobalt sulphide concentrate, which is shipped to Japan for treatment. At rated capacity, Marinduque will produce some 1.5 million kg of cobalt in mixed sulphides a year.

Australia. The Greenvale nickel project appears to have overcome many of the operating difficulties that plagued it during its early years of operation. Although refined nickel production has been over 90 per cent of capacity at times, production of the mixed cobalt-nickel sulphide concentrates has only been at about 60 per cent of planned capacity. Rated capacity for cobalt is 1.25 million kg a year in the mixed sulphide concentrate, which is also shipped to Japan for treatment. Further improvements are expected.

Western Mining Corporation Limited produces a mixed nickel-cobalt sulphide concentrate as a byproduct of its nickel refinery operation at Kwinana. The plant has been producing between 400 and 600 tonnes a year of the mixed sulphide concentrate, which contains about 20 per cent cobalt. Refining capacity at the plant was increased by 50 per cent in 1975 and 1976, and the increase will likely result in a small increase in cobalt production.

Japan. Nippon Mining Co. Ltd.'s wholly-owned subsidiary, Nikko Nickel-Cobalt Smelting Company, began sample deliveries of cobalt metal in October and is expected to begin commercial production in 1977. Feed material for the plant comes from the Greenvale project in Australia. Plant capacity is about 1 200 tonnes a year of cobalt.

Sumitomo Metal Mining Co. Ltd. started its new cobalt refinery at Nuihama in January at the rate of 30 tonnes a month and upped that to 60 tonnes a month in May. The feed is mixed nickel-cobalt sulphides from Marinduque's nickel refinery in the Philippines. Eventual capacity is about 1 200 tonnes a year.

Mexico. A gold-cobalt deposit is currently being investigated by a Mexican subsidiary of Blythwood Mining Company Limited of Vancouver. Tunnels were intially driven into the orebody in the 1930s. Recent samples from these tunnels contain up to 0.3 per cent cobalt.

United States. AMAX Inc.'s nickel refinery at Port Nickel, Louisiana is scheduled to reach full capacity in 1977. The rated capacity of the cobalt circuit is some 450 tonnes a year. Cobalt production in 1976 was approximately 160 tonnes.

Cuba. Cuba plans to increase its nickel production from its present level of about 30 000 tonnes a year to over 100 000 tonnes a year in the 1980s. The Cuban nickel deposits contain about 0.1 per cent cobalt. At present there is believed to be little cobalt recovered. However, the Cuban government has indicated that recovery of associated metals will have a greater priority and, if this is the case, Cuba could become a fairly important supplier of cobalt in the near future. Present output is sold mainly to the USSR.

Indonesia. The lateritic nickel project of P.T. International Nickel Indonesia, in which Inco holds a controlling interest, is scheduled to start production in March 1977. Initial capacity is 16 million kg of nickel in nickel matte. A second stage, scheduled for completion in 1978, will boost capacity to about 45 million kg of nickel in nickel matte. There is also some cobalt in the matte. How much of this cobalt will be recovered is open to question because the nickel matte will be shipped to Inco's Clydach, Wales nickel refinery, which will have the capability of producing either Class I nickel products, which permit recovery of cobalt or Class II products, which do not; and to Japan, where some of the matte will be converted to Class II nickel products. Maximum recoverable cobalt in the matte is likely to be in the order of 1 000 tonnes for the first stage, rising to 2 500 tonnes on completion of the second stage. Actual recovery will probably be below these figures.

Consumption and uses

Cobalt was first used over 2 000 years ago as a colouring agent for glass. The use of cobalt as a colouring agent in glass and ceramics dominated cobalt usage up to the early 20th century. At that time, research into the properties of metals like cobalt was stimulated by technological demands, and the use of cobalt in alloys rapidly replaced colouring agents as the most important consumer of cobalt. Cobalt's use in alloys stems principally from three properties: its relatively high melting point, its corrosion resistance and its ferromagnetism.

Cobalt usage is divided approximately as is shown in the following listing:

Use	Percentage of Consumption[e]
High Temperature Uses	20
Magnetic Uses	25
Wear and Abrasion Resistant Uses	20
Pigments, Colouring Agents	20
Chemical Uses	10
Other	5

[e] Estimated.

Cobalt-base, high temperature alloys or superalloys find their principal application in parts for jet engines. Cobalt-base superalloys contain from 20 to 65 per cent cobalt and can withstand temperatures up to about 900°C under conditions of low stress. Smaller amounts of cobalt are also contained in nickel- and iron-base superalloys. A growing area of use for cobalt-base superalloys is in parts for gas turbines.

Cobalt is one of very few materials that exhibit magnetic properties at room temperatures, the other major metals being iron and nickel. Cobalt is a component of almost all permanent magnet materials, materials which retain magnetic properties once the original magnetizing field is removed. Cobalt serves three major purposes:

(1) it increases coercivity, the amount of equivalent force needed to demagnetize a permanent magnet;
(2) it is the only element that increases the saturation magnetization of iron; and
(3) it has a much higher Curie temperature, the temperature at which a material loses its magnetic properties, than does iron and nickel. This property makes it possible to heat-treat cobalt-containing permanent magnets without loss of magnetic properties.

There are a wide range of permanent magnet materials, varying from iron-cobalt alloys to the Alnicos (aluminum-nickel-cobalt alloys) to cobalt-rare earth alloys. Nearly all of these magnetic alloys are used in electrical or electronic applications such as compact circuits, electrical motors, loudspeakers and telephones.

In the production of cemented carbide cutting tools, cobalt is used as a binder or metal matrix. Because of the extremely high melting points of the commonly used carbides, such as tungsten carbide, the cutting tools are made by heating a briquetted mixture of the carbide and cobalt. The cobalt melts and binds the hard carbides, providing the matrix that will give the toughness and shock resistance needed in their varying applications, such as drill bits, dies and lathe tools. Cobalt content can vary from 3 per cent to 35 per cent in some dies.

Cobalt-base alloys are also used for cutting purposes. The most important group of cobalt-base alloys are the stellite group, containing cobalt, tungsten and chromium as their principal constituents. Stellites are suitable for a variety of uses. For example, their hardness and strength are mainly exploited for cutting tools and hard-wearing parts of machinery such as in agricultural implements and excavating equipment. Their properties of corrosion resistance and ability to take a high polish are exploited by chemical plants dealing with acids and for exhaust valves in motors. These cobalt-base nonferrous alloys can also be used as hardfacing materials. Coating of a part with a particular cobalt alloy can provide greater resistance to abrasion, heat, impact and corrosion. Hardfacing alloys are most widely employed in the manufacture and repair of parts subject to abrasive conditions such as ball mill liners, parts of crushing equipment and the teeth of power shovels.

Cobalt is used in high-speed tool steels to increase the red hardness of the steel or its ability to be used at higher rates of speed and for deeper cuts than would be the case if cobalt was not present. The cobalt content can range from 2 to 12 per cent. Cobalt is also used in some abrasion-resistant die steels. Generally, cobalt additions are more costly than other additions and this has been an important factor in minimizing the usage of cobalt-containing steel.

In its metallic form, cobalt is also used in glass to-metal seals, dental and surgical alloys and in springs. Its isotope, cobalt 60, is used in place of X-rays or radium as an inexpensive source of gamma rays for the inspection of internal structures and for cancer treatment.

The most important nonmetallic form of cobalt is cobalt oxide. Cobalt oxide additions of from 150 to 4 500 grams per tonne of glass will impart a blue colour. Smaller additions, up to 45 grams a tonne, are made to neutralize the yellow tint of iron in plate and window glass. Similarly, cobalt is used in ceramics to neutralize the iron colour in pottery tile and sanitary ware. Larger additions are used to impart a blue or violet colour to the ceramics. Cobalt oxide is also used to eliminate the iron colour in white porcelain, and in quantities of 0.2 to 2 per cent to promote the adherence of the enamel to steel.

Cobalt chemicals are used as dryers and pigments in paints and in the synthesis of liquid hydrocarbons. Since cobalt is a constituent of vitamin B_{12}, cobalt is also added to soil or herbage to maintain the health of cattle and sheep in some areas of the world where the cobalt content of the vegetation is too low.

Prices

There were three increases in the North American price during the year; one in April, one in September and one in December. Cobalt metal prices for Zaire cobalt rose from $4.00 a pound at the beginning of 1976 to $4.40 a pound in April, $4.90 a pound in September and $5.40 a pound on Christmas eve.

Outlook

In 1977 demand should increase slightly. Mine supplies should also increase in 1977, particularly with the resolution of the transportation difficulties in Africa, and should be adequate to meet demand. A price increase may occur, however, if consumers try to increase their stock levels and thereby place a strain on supply.

Beyond 1978, the situation in Africa poses concern for consumers. The adequacy of world supplies is dependent on a continued flow of cobalt from Zaire and Zambia and any disruption of supplies from these sources will cause acute world shortages. While the present transportation system in Africa is adequate to handle raw material exports, any increase in the demand for raw materials will place great stress on the rail line from Zaire to the Republic of South Africa. This line must now handle its normal traffic, plus all traffic to and from Rhodesia now that Zambia and Moçambique have closed their borders to Rhodesia, and to the material from Zaire. Any economic boom is likely to create an artificial shortage due to rail and port congestion in the Republic of South Africa if alternate means of transporting cobalt from Zaire are not found.

The medium-term outlook for cobalt supplies is one of increasing mine production. The increase in supply will, however, probably not be sufficient to meet demand until some of the projects commissioned for 1977 and 1978 come into full production. Beyond this, further new production may come from developments of nickel deposits and from the development of the Tenke-Fungurume deposit in Zaire. However, these increases may not be sufficient to meet demand in the 1980s.

In the long term, the possibility of cobalt produced from seabed mining operations is the largest potential source of supply. If production from the seabed commences, there will probably be a surfeit of cobalt. However, seabed mining is not expected to be a major factor in world cobalt supplies until the 1990s.

Prices of cobalt in U.S. currency

	Dec. 1975	Dec. 1976
	($U.S.)	($U.S.)
Cobalt metal per lb. f.o.b. New York, Chicago Shot 99%+		
less than 50 kg	4.10	5.05
50-kg drums	4.05	4.96
250-kg	4.00	4.90
Powder, 99%+, 300 and 400 mesh		
50-kg drums	5.41	8.36
extra fine, 125-kg drums	7.05	8.29
S grade, 10-ton lots	4.00	5.25

Source: *Engineering Mining Journal*, December 1975 and 1976.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
33200-1	Cobalt ore	free	free	free	free
35103-1	Cobalt metal, excluding alloys, in lumps, powders, ingots or blocks	free	free	25	free
35110-1	Cobalt metal, in bars	free	10	25	free
92824-2	Cobalt oxides	free	10	20	free
92824-1	Cobalt hydroxides	10	15	25	10

United States

Item No.		
601.18	Cobalt ore	free
632.20	Cobalt metal, unwrought, waste and scrap	free
632.84	Cobalt metal alloys, unwrought	9% ad. val.
633.00	Cobalt metal, wrought	9% ad. val.
418.68	Cobalt compounds other than cobalt oxide and cobalt sulphate	6% ad. val.
426.24 } 426.26 }	Cobalt salts	6% ad. val.
418.60 418.62	Cobalt oxide and } Cobalt sulphate }	1.2¢ per lb.

Sources: Canada — The Customs Tariff and Amendments, Department of National Revenue Customs and Excise Division, Ottawa; United States — Tariff Schedules of the United States Annotated (1976) TC Publication 749.

Columbium (Niobium) and Tantalum

ALBERT BOUCHARD and R. JOHNSON

Columbium producers had a poor year in 1975 due to the world-wide economic recession which brought about a sharp reduction in world consumption compared to previous years. However, in 1976 the situation improved, primarily because of increased use of high-strength, low-alloy (HSLA) steels in various industrial sectors such as pipeline construction, the automobile industry and as structural steels. HSLA steels, which were virtually unknown 15 years ago, are now steadily increasing in importance. The addition of columbium in these steels increases their strength by close to 50 per cent, an important factor in several fields where the strength-to-weight ratio is a primary consideration. At present, the HSLA steel industry consumes more than 80 per cent of all columbium produced. In this application the columbium is in the form of ferrocolumbium.

The use of columbium as a superconductor is becoming increasingly important and various research and development projects are exploiting this property. At present, consumption for superconductive applications is comparatively small, but future commercial applications of these products should substantially increase the world consumption of columbium.

Canada

At the present time there are three companies in the world which are working pyrochlore deposits. The first, and by far the most important, since it alone provides close to 75 per cent of world production, is the Companhia Brasileira de Metalurgia e Mineracao (CBMM) with its mining operation in the Araxa region of Brazil. The two other mines are Canadian, and are located in the province of Quebec. These are St. Lawrence Columbium and Metals Corporation, with its mining operation near Oka, and Niobec Inc. near Chicoutimi, which commenced production during 1976. Canadian production (shipments) of concentrates with a columbium pentoxide content estimated at 1 655 612 kilograms (kg), is valued at $6 935 000 for 1976 compared with 1 661 567 kg valued at $6 854 430 in 1975. Most of the columbium produced is exported to various countries for conversion to ferrocolumbium for use by the steel industry.

St. Lawrence Columbium and Metals Corporation (SLC) of Oka, Quebec, had a number of setbacks in 1976. The company was forced to halt all production from the beginning of February 1976 because of a strike of its underground employees. At the time the strike was called, SLC was seeking a partner to finance a major expansion project based on the discovery of important ore reserves on a property adjacent to the present operation. During July, because of serious financial problems, in addition to those caused by the long strike, all the assets of SLC were seized by its preferred creditors — the Canadian Imperial Bank of Commerce and General Trust of Canada. Following this seizure, SLC declared bankruptcy in order to reimburse its numerous small general creditors. During the following months, SLC made a number of efforts to find new capital, but was still without success by the end of 1976. At the beginning of 1977 all the assets were put up for sale by the preferred creditors.

During 1976 a new producer, Niobec Inc., entered the columbium market. Niobec's mine and concentrator are at St-Honoré near Chicoutimi, Quebec. The ownership of this company is shared equally between Quebec Mining Exploration Company (SOQUEM) and Teck Corporation Limited. Niobec Inc. is working a pyrochlore deposit by an open stope method. Blasthole stoping techniques are used to extract the ore. The proven reserves are in the order of 8 500 000 tonnes* with a Cb_2O_5 content of 0.72 per cent. Production commenced in January, 1976 and the first shipments of concentrate were made in May. The mill can handle 1 360 tonnes a day, and produces a concentrate with 60 per cent Cb_2O_5 content. A novel concentration method known as "preflotation" is used. This technique is based on the use of oxalic acid rather than hydrofluoric acid, the reagent ordinarily used for flotation of the pyrochlore. It consists basically of floating most of the carbonates before flotation of the pyrochlore. This procedure gives a good-quality concentrate and excellent yield. The annual production capacity is in the order

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

$(Na, Ca)_2 (Cb, Ta)_2O_6F$. Minerals of this series are often rich in rare earths and radioactive elements and are found almost exclusively in carbonatite-alkalic rock complexes. The principal world reserves of columbium are the pyrochlore deposits of Canada and Brazil. Columbite and tantalite are also sources of columbium and tantalum. In Nigeria, for example, a concentrate having a 65 per cent or greater content of combined oxides of columbium and tantalum is obtained as a byproduct from the tin mines. There are more than 30 carbonatite deposits known in Ontario, as well as several in Quebec, Labrador, British Columbia and the Northwest Territories. The principal columbium mineral deposits in carbonatite complexes are:

- in Quebec: the St. Lawrence Columbium and Metals Corporation mine, near Oka; the properties of Columbium Mining Products Ltd., Main Oka Mining Corporation and Columbium Limited, all situated in the Oka region; the Niobec Inc. mine at St-Honoré, near Chicoutimi.
- in Ontario: the deposits at James Bay, at Manitou Island near North Bay, and at Lackner Lake and Nemegosenda Lake, near Chapleau.

Prices

During 1976 the variation in prices of columbium concentrates has been due chiefly to increases in mining costs and ore treatment. Prices published by the U.S. Department of the Interior indicate that Canadian pyrochlore fob mine was more than $3.44 per kg of Cb_2O_5 content in the concentrates at the first of January 1976, and more than $4.41 at the end of 1976. Columbite ore cif United States ports, priced at $3.97 to $4.19 per kg of pentoxide content at the beginning of 1976, was priced at $6.61 to $7.72 by the end of the year. These prices refer to material having a Cb_2O_5:Ta_2O_5 ratio of 10:1.

Outlook

Although a second columbium producer appeared on the Canadian market in 1976, the Canadian production of pyrochlore concentrates was smaller than that in 1975. This was due to the long strike and subsequent bankruptcy of the St. Lawrence Columbium and Metals Corporation. An improvement in the 1977 figure is unlikely unless Niobec Inc. produces at full capacity. By the end of 1976, there was still no decision whether the SLC operation would reopen.

In 1977 and the years that follow, demand for columbium should have a significant growth, due for the most part to the construction of pipelines in various parts of the world. The steels used in the construction of these pipelines contain about 0.6 kg of columbium per tonne of steel. Thus, a pipe 122 cm in diameter with a 1.9 cm wall thickness will require approximately 340 kg of columbium per kilometre. This indicates the magnitude of the quantities of columbium required in these projects. An annual increase in world demand o columbium of about 10 per cent per year is foreseen for the coming years.

TANTALUM

Canada has only one producer of tantalum concentrates, Tantalum Mining Corporation of Canada Limited at Lake Bernic, Manitoba. In 1976 production dropped some 30 per cent as a result of a three-month strike at the mine. There is presently no processing of tantalum concentrates done in Canada.

Tantalum was in short supply in 1976 as demand rebounded from the low levels of 1975. Conversely, world production declined, principally as a result of the lower production in Canada. Spot tantalum concentrate prices rose about 20 per cent during the year as did those of tantalum metal powder.

The supply shortage is expected to continue into 1977 and further price increases can be anticipated. In the longer term, it is unlikely that existing sources of supply will be sufficient to satisfy demand. While the immediate answer to the problem of tantalum availability is the recovery of tantalum from low-grade tin slags, new mine sources must be found if a long-term shortage is to be averted.

Minerals and occurrences

In nature, tantalum and columbium are almost invariably found together because of their chemical similarity, their nearly identical atomic radii and the similarity in their atomic structures and valences. The principal source of tantalum is the columbite-tantalite series which is an isomorphous series of iron, manganese, columbium and tantalum oxides. The general formula for the columbite-tantalite series is $(Fe,Mn) (Cb,Ta)_2O_6$. The mineral is called tantalite if the tantalum pentoxide (Ta_2O_5) content in the mineral exceeds the columbium pentoxide (Cb_2O_5) content, and columbite if the reverse is true. The only other major commercial source of tantalum is the microlite-pyrochlore series which has the general formula $Ca_2(Cb,Ta)_2O_6 (OH,F)$. Similarly, the mineral here is called microlite if the tantalum content exceeds that of columbium, and pyrochlore if the reverse is true.

These minerals are found in granitic pegmatites and in alkalic igneous rock complexes. Of these two general types, the granitic pegmatites, or residual and alluvial deposits derived from such rocks, are by far the most important source of tantalum. There are two basic mine sources of tantalum: deposits in which the tantalite-columbite series or the microlite-pyrochlore series are the principal minerals of interest; and deposits in which tantalite-columbite is recovered as a byproduct of tin-mining operations.

Following production of a tantalum-columbium concentrate, the next major processing step is the separation of tantalum and columbium. This is usually accomplished by dissolving the concentrate in hydrofluoric acid, followed by leaching with water and hydrochloric acid to remove impurities. Anhydrous hydrogen fluoride and potassium hydroxide are then added and the solution heated. This creates potassium-tantalum fluoride (K_2TaF_7) and potassium-columbium fluoride (K_2CbF_7). The potassium-tantalum fluoride is then separated from the potassium-columbium fluoride by solvent extraction. The potassium-tantalum fluoride can then be reduced with sodium or carbon, or by electrolysis, to produce a pure tantalum metal powder.

Cassiterite (tin) deposits, such as those in Thailand, Zaire and Portugal, often contain important quantities of tantalite and columbite. During the concentration of the cassiterite, most of the columbite and tantalite is removed by magnetic separators and is subjected to the process described above. Some of the tantalite and columbite does, however, remain in the concentrate and is only separated during the smelting of the concentrate, where it goes off in the slag. The recovery of tantalum from tin slags has become a major source of tantalum. The processes used are regarded as proprietary by the companies who process the tin slags and details of these processes are not available.

At present prices and with current technology it appears that an overall grade of about 8 to 10 per cent Ta_2O_5 is necessary to permit economic recovery of tantalum from tin slags. To date, the major source of these slags have been Thailand. There are, however, slags produced in several other countries where the tantalum content is considerably below 8 per cent Ta_2O_5. These slags represent a potentially important source of tantalum, not only for the amounts that are produced each year but for the large amounts that have accumulated in slag piles around the world. Development of processes capable of treating these lower-grade slags has been an area of major interest among consumers. One company, Fansteel Metallurgical Corporation, has reportedly purchased 500 000 tonnes of Malaysian tin slag averaging about 2.7 per cent Ta_2O_5 in anticipation that the process it is currently working on will become commercially viable. Similarly, Kawecki Berylco Industries Inc. has also been working on a process to recover tantalum from low-grade tin slags that will be tested in Europe this year. If these processes are successful, the availability of tantalum will be greatly increased — possibly at the expense of mine production in the short term.

Canada, production and trade

There are several known occurrences of tantalum in Canada. The most important of these is the zoned pegmatites near Bernic Lake in Manitoba. Most of the tantalum in this deposit occurs as stanniferous tantalite in small disseminated grains ranging in size from a pinpoint to one-eighth of an inch long. The chemical composition of the tantalite shows that it contains 70 per cent tantalum pentoxide (Ta_2O_5), 1.3 per cent columbium pentoxide (Cb_2O_5) and 13 per cent tin oxide. This deposit is the world's largest single mine source of tantalum. The other occurrences known in Canada are either too small or of too low a grade to be considered economic at the present time. Some tantalum was produced from an occurrence in the Northwest Territories in the 1950s; however, the mining operation was deemed to be uneconomic, and production ceased within two years of start-up.

There is only one producer of tantalum concentrates in Canada, Tantalum Mining Corporation of Canada Limited (Tanco) from its mine and mill at Lake Bernic, Manitoba. The mill has a capacity of some 450 tonnes of ore a day, which gives Tanco the capability of producing upwards of 190 000 kg of tantalum pentoxide (Ta_2O_5) in concentrate a year. Tanco's 1976 production of 127 813 kg of Ta_2O_5 in concentrate was much lower than expected because of a three-month strike.

Tanco has made several additions to its mill in recent years aimed at increasing overall mill recovery rates. The latest addition is a new section that will recover tantalite from the slimes in the tailings. This section was commissioned in late 1975 and once it becomes fully operational, it is expected that overall mill recovery will be increased by about 5 per cent to between 75 and 80 per cent.

Table 3. Production of Ta_2O_5 in concentrate by Tantalum Mining Corporation of Canada Limited, 1969-76

Year	Ta_2O_5 contained in concentrate (kg)
1969	74 521
1970	192 367
1971	161 496
1972	147 911
1973	24 954
1974	121 777
1975	181 009
1976	127 813

Source: Quarterly Bulletin of the Tantalum Producers International Study Centre.

In 1976 Tanco conducted a $250 000 underground drilling and exploration program. An additional 160 000 tonnes of reserves were identified, as well as some 300 000 tonnes of low-grade ore. While this low-grade ore is marginal at current prices, an increase in price or further improvements in mill recovery rates could make it economic. At the end of 1976 mineable reserves stood at some 1.17 million tonnes averaging 0.179 per cent Ta_2O_5, an amount sufficient to continue mining at present rates for another six or seven years. It has only been in the last two years, when Tanco has made a profit, that the company has really been able to undertake some exploration work. It is hoped that Tanco will be able to improve its reserve position through further exploration in 1977.

Tanco is 50.1 per cent owned by International Chemalloy Corporation, 25.0 per cent by the Manitoba Development Corporation, a provincial crown corporation; and 24.9 per cent by Kawecki Berylco Industries, Inc. International Chemalloy was placed in receivership in March of 1975 following an allegation that it had defaulted on a loan. The president of the Manitoba Development Corporation (MDC) indicated this year that MDC will consider purchasing International Chemalloy's interest in Tanco if it appears likely that International Chemalloy will be in receivership for an extended period.

There is currently no processing of tantalum concentrates carried out in Canada. All of Tanco's production is exported, with the United States being the principal market. All of Canada's requirements of higher processed forms of tantalum are met by imports.

Tantalum in 1976

Tantalum demand increased in 1976 finally reversing the fall in tantalum consumption which began in late 1974. The increase in demand occurred principally in Japan where consumption rose an estimated 30 per cent and in the United States where consumption rose some 25 per cent. The recovery was fuelled primarily by an increased demand for tantalum capacitors and, to a lesser extent, by increased demand for tantalum carbide by the cutting tool industry.

Table 4. Estimated world production of tantalum, 1974-76

	1974	1975	1976
	(000 tonnes Ta_2O_5)		
Concentrates			
Canada	122	181	128
Brazil	60		
Australia	95		
Nigeria	125		
Mocambique	50	430	410
Zaire	15		
Malaysia	10		
Other Market Economies	35		
USSR	240	. .	. .
Tin Slags			
Thailand	400	. .	. .
Stockpile Releases			
GSA	490	48	4
Total	1 640	. .	. .

Source: Department of Energy, Mines and Resources.
. . Not available.

On the other hand, world mine production of tantalum in concentrates and in slags is believed to have declined, possibly by as much as 15 per cent, in 1976. The lower production was primarily the result of the three-month strike at Tanco and reduced production in Nigeria. World production figures for tantalum are difficult to establish accurately because the tantalum content of columbite concentrates and of tin slags is often either not reported or is reported together with the columbium content as a gross figure. The increase in consumption, coupled with the lower production, resulted in tantalum being in short supply for much of 1976. Reports indicate that there was a general run-down of consumer inventories in most countries during the year as a result of this situation.

The principal international development during the year was the stoppage of releases of tantalum-bearing materials from the General Services Administration (GSA) stockpile in the United States. The releases were stopped in September when the Federal Preparedness Agency recommended that the stockpile objectives for tantalum be increased to levels which exceeded present holdings. The stockpile objectives and present holdings are as follows:

Materials	*Objective*		*Present*
	New	*Old*	*Holdings*
	(000 kg Ta)		
Tantalum-bearing Minerals	2 473	142	1 154
Tantalum Carbide	403	1	13
Tantalum Metal	748	20	91

Releases from the GSA stockpile have been an important factor in the tantalum market. For example, in 1974 GSA releases accounted for almost 30 per cent of the tantalum supplied to the market. The loss of this potential source of supply will likely be felt in 1977. There are no immediate purchases planned to bring holdings into line with the new objectives.

Products and uses

The uses of tantalum stem from its chemical and physical properties:

1. its ability to form an oxide film which has excellent dielectric properties;
2. its resistance to chemical attack at moderate temperatures;
3. its high melting point;
4. its strength and ductility; and
5. its ability to form stable carbides.

Its prinicpal uses are in electronic components, in chemical processing equipment and in cutting tools and dies.

The largest single usage of tantalum is in electronic components, principally capacitors. Tantalum has enjoyed a rapid growth in this field because it has the highest dielectric constant of any known metal oxide and the ability to transmit alternating current in only one direction. Capacitors made with tantalum have become the standard for reliability among electronic capacitors. In addition to high reliability, tantalum capacitors also have a long shelf life and, because of tantalum's high dielectric constant, are smaller for an equivalent capacitance than capacitors made of other materials. Until fairly recently, tantalum capacitors were relatively high-priced; however, the metals' reliability gained markets for it in industrial and military applications where reliability is highly prized, and in some cases, essential. Recently, tantalum capacitors have begun to make some inroads into consumer products; however, this area is far more price-competitive because the producers' requirements for reliability and performance are less stringent than in the case of industrial or military products. Tantalum capacitors usage in industrial and military goods would seem to be almost price-inelastic, while their use in consumer goods will depend primarily on price-competitiveness with other types, such as aluminum capacitors. Generally the trend towards miniaturization of electronic circuits will reduce the size, and therefore the weight, of tantalum capacitors required. This factor, however, will be more than compensated for by a wider usage of tantalum capacitors. Indeed, recent research has been successful in further increasing the dielectric properties of tantalum by reducing the tantalum grain size, which should make it an even more attractive material. In addition to its use in capacitors, minor amounts of tantalum are used in rectifiers, in signal and alarm devices and in vacuum and electronic tubes.

Tantalum finds a use in corrosion-resistant applications because of its relative chemical inertness. The oxide film which forms on the surface of tantalum metal is very stable and seems not only to retard further oxidation of the metal, but is also soluble in very few corrosive media. Because the film remains relatively thin it does not impede heat transfer. These properties, in addition to its ability to maintain its strength and corrosion resistance at moderate temperatures, find it many uses in corrosion-resistant applications. It is used as a lining of vessels used in the production of hydrochloric acid, hydrogen peroxide, bromine and several high-purity chemicals, and in the recovery of sulphuric acid. Its ability to transmit heat is utilized in heat exchangers, condensers, coils and other such parts. In addition to these uses, these same properties account for its use in surgical implants, nuclear reactors and laboratory equipment. Tantalum can be substituted for by columbium; however, tantalum usually has a much longer service life, so to replace or retard tantalum's growth in these areas will require a wide price differential.

Tantalum carbide, when mixed with other metallic carbides, usually imparts to the mixture greater shock resistance, greater resistance to cratering and edge wear, and greater strength. Tantalum carbide is used in cutting tools that are employed in making heavy cuts, such as are called for in the steel industry. The tantalum carbide content can range from 1 to 15 per cent in these mixtures but usually averages around 5 per cent. In addition to cutting tools, tantalum carbides are also used in dies and some parts for metalworking machinery, where it improves the resistance to cratering and also the anti-welding characteristics of the part. Tantalum carbide is the most expensive of the commonly used metallic carbides and this certainly has limited its usage. However, it does not appear to have a wholly satisfactory substitute, so this is expected to remain a minor growth area.

Tantalum is also used in some superalloys which are employed in aerospace structures, jet engines and gas turbines where strength at elevated temperatures and corrosion resistance are required. Historically, one of the important uses of tantalum has been in the steel industry where ferrotantalum and ferrocolumbium-tantalum are used as grain refiners in carbon steels and as carbide formers in alloy steels. However, this usage is gradually disappearing as ferrocolumbium performs the same functions at a much lower cost. Tantalum is not widely used in chemicals because of its relative inertness.

About 70 per cent of tantalum usage is as a metal powder, principally in the manufacture of electronic components, although minor amounts are used as alloying agents. Tantalum carbide accounts for about 15 to 20 per cent of the tantalum used, and tantalum mill products for another 10 per cent. Less than 5 per cent is used in ferroalloys and chemicals.

Approximately 10 to 12 per cent of world demand is met by recycled material. This is recovered from old capacitors, tantalum metal parts and turnings, and cutting tools and dies. It is expected that the percentage of tantalum demand supplied by recycled material will increase, and eventually stabilize at around 20 per cent.

Prices

In recent years, Tanco has adopted the policy of setting prices at the beginning of each year and sticking to them throughout. In 1976, Tanco's concentrate price was \$16.00 a pound Ta_2O_5, an increase of about 7 per cent over 1975. At the beginning of the year, spot prices for concentrate of a grade equivalent to that of Tanco were selling for about the same price. However, as it became evident that a supply shortage was developing, these spot prices rose and by year-end were \$2.00 to \$3.00 a pound above Tanco's prices. Tanco has announced a price increase effective January 1, 1977 that will raise its concentrate price by \$1.75 a pound of Ta_2O_5 to \$17.75 a pound.

Prices of tantalum powder also rose during the year after more than a year with no price increases. By year-end, spot metal prices had risen some 20 per cent and stood at about \$40 a pound for low voltage capacitor-grade powder and about \$48 a pound for high voltage capacitor-grade powder. The prices for tantalum mill products rose about 10 to 15 per cent during the course of the year.

Outlook

Demand is expected to increase in 1977. Although world production should rise, with Tanco operating for a full year, it is unlikely that this will avert a further shortage, particularly following the rundown of consumer stocks in 1976 and with the loss of the GSA as a source of supply. Reportedly, Tanco has already contracted all of its output for 1977 and it is also reported that Thai tin slags are sold out beyond 1977. Prices will be under considerable pressure during the year and substantial increases in the spot concentrate and metal prices can be expected.

There must also be some concern for the medium- and long-term availability of tantalum. While increased prices and the effort spent on research and development will likely see tantalum being recovered from low-grade tin slags in the short-term, these stockpiled slags represent a finite reserve. The depressed prices which prevailed for much of the early 1970s acted as a disincentive to exploration for tantalum. Additional mine sources will be required by the mid-to late-1980s if a long-term shortage is to be averted.

Prices

The prices below are in American currency and were quoted in *Metals Week* of December 31, 1976.

	1976 ($)	1975 ($)
Columbium ore columbite, per pound of pentoxide, cif U.S. ports	3.00-3.50	1.80-1.90
Canadian pyrochlore, per pound Cb_2O_5, fob mine or mill, contract only. (Quoted in *Mineral Industry Surveys.)*	2.00-2.20	1.56
Brazilian pyrochlore, per pound Cb_2O_5, fob shipping point, contract only	2.25	(1.42)
Ferrocolumbium, per pound Cb, fob shipping point		
low alloy	4.73	4.30
high purity alloy	11.80-14.30	8.61-9.50
Columbium metal, per pound, 99.5 – 99.8%, depending on importance of order		
	Powder Roundel	Ingot
Reactor	30.00-45.00	18.00-25.00
Tantalum metal per lb powder fob shipping point depending on size of lot	35.40-48.00	(35.40-44.50)
Sheet and rod depending on grade	48.00-118.00	

Customs Tariffs

Canada

No.		British preferential tariff	Most favoured nation tariff	General tariff
32900-1	Columbium and tantalum ore and concentrate	exempt	exempt	exempt
35120-1	Columbium and tantalum metals and alloys in powder, pellets, scrap, ingots, sheet, plate, bars rods or wires for use in Canadian manufacturing. (Expires 31 Oct. 1977)	exempt	exempt	25%
37506-1	Ferrocolumbium, ferrotantalum and ferrotantalum-columbium	exempt	5%	5%

Customs Tariffs (cont'd)

United States

601.21	Columbium ore and concentrate	exempt
601.42	Tantalum ore and concentrate	exempt
628.15	Columbium metal, unwrought, scrap and rejects	5%
628.17	Columbium alloys, unwrought	7.5%
628.20	Columbium metal, wrought	9%
629.05	Tantalum metal, unwrought, scrap and rejects	5%
629.07	Tantalum alloys, unwrought	7.5%
629.10	Tantalum metal, wrought	9%

Sources: Canadian Customs Tariffs and Amendments, Revenue Canada, Customs and Excise, Ottawa. Tariff Schedules of the United States Annotated (1976) TC Publication 749.

Copper

G.E. WOOD

The year 1976 was one of world economic recovery. This was reflected in a rise in world copper consumption of 14.6 per cent. As large as it was, this increase was insufficient to prevent further net stock increases over the full year as idle capacity was reactivated and major new mines came into production. Prices were erratic but ended the year substantially higher than the depressed level at which they closed one year earlier.

Supply disruptions occurred in Africa due to the Angolan civil war and guerilla activity along the Benguela railway.

Discussions between copper consuming and producing countries began in 1976, within the United Nations Conference on Trade and Development. An intergovernmental expert group was formed to examine the problems of the industry and make recommendations early in 1977.

The United States announced new goals for its strategic stockpile during 1976. The new goal for copper is 1.2 million tonnes*, compared with its current holding of 18 000 tonnes. Japan also commenced purchasing of copper for its national stockpile in mid-1976.

The intergovernmental council of copper exporting countries (CIPEC) expanded its membership during 1976 to eight by the admission of Mauritania as an associate member. Official reductions in copper production and deliveries by CIPEC members were terminated at the end of June.

In Canada new mine development took place at a reduced pace. Progress was made towards the construction of two new smelters and the modernization of one established smelter. A new hydrometallurgical process for production of copper was successfully tested on pilot plant scale.

Canadian mines

Primary production of copper in Canada increased to 747 131 tonnes in 1976 compared with 733 826 tonnes in 1975, an increase of 2 per cent. Many mines operated at less than full capacity, leaving the potential for further production increases in 1977.

Production costs in Canadian mines continued to escalate in 1976. For many producers, total costs, including depreciation charges, exceeded $0.60 a pound by the end of the year.

Demand and prices recovered somewhat but nevertheless remained at lower-than-normal levels. The market outlook and prices of other metals co-produced in Canadian mines: nickel, zinc, lead, molybdenum and the precious metals, was better in most cases than for copper, giving relief to some producers.

The depressed state of copper prices during 1976 led to decisions for further mine closures in Quebec. Sullivan Mining Group Ltd. announced its intention to close its operations at Cupra and D'Estrie in the Eastern Townships, and Madeleine Mines Ltd. decided to close its Gaspé mine early in 1977.

Newfoundland. Consolidated Rambler Mines Limited reduced the operating rate to a one-shift, five-days-a-week operation effective September 14, 1976. This action resulted from restrictions on the amount of Rambler concentrate which could be handled at the Gaspé smelter of Noranda Mines Limited, sole purchaser of the mine's output.

New Brunswick. The operations of Brunswick Mining and Smelting Corporation Limited were affected by a three-month labour strike which was settled in mid-August. The estimated capital cost of the project to expand No. 12 underground mine capacity from 5 760 tonnes to 9 980 tonnes a day by 1979 increased from $51 to $53 million, primarily due to inflation. Operating costs in 1976 increased overall by 15 per cent.

Heath Steele Mines Limited completed the mining of the remnants of its A-mine orebody in 1976. Expansion of the mine and sinking of the new No. 5 shaft will increase the daily tonnage milled to 3 600 tonnes in 1977.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Quebec. The Norita mine of Orchan Mines Limited began commercial production on May 1, 1976. Preproduction development ore was milled from January to the end of April. Ore is transported by truck from the mine to the Orchan mill.

Noranda Mines Limited continued to restrict capital spending throughout 1976. As a result, the further development of the Rouyn-Noranda metallurgical complex was deferred. When the program of constraint was introduced during 1975 the construction of a sulphuric acid plant at Noranda was curtailed. Introduction of the use of oxygen-enriched air in the Noranda continuous reactor enabled a 30 per cent increase in the throughput rate and a reduction in fuel consumption in the reactor. The Noranda complex continued to face a tight supply situation for copper

(text continued on page 183)

Table 1. Canada, copper production, trade and consumption 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
British Columbia	258 518	363 339 226	273 541	412 308 000
Ontario	257 778	361 431 937	258 980	390 361 000
Quebec	117 556	165 221 062	120 411	181 500 000
Manitoba	64 495	90 645 504	56 686	85 444 000
Yukon	8 487	11 928 559	11 039	16 639 000
New Brunswick	11 212	15 758 008	9 677	14 587 000
Saskatchewan	7 905	11 109 902	9 596	14 463 000
Newfoundland	7 500	10 541 388	6 764	10 194 000
Northwest Territories	375	526 889	437	660 000
Total	733 826	1 030 502 475	747 131	1 126 156 000
Refined	529 199	. .	510 468	. .
Exports				
Copper in ores, concentrates and matte				
Japan	226 885	222 384 000	215 932	223 017 000
United States	48 976	43 688 000	53 659	52 322 000
U.S.S.R.	—	—	12 410	16 369 000
Norway	16 881	15 631 000	16 636	13 718 000
West Germany	11 907	9 423 000	3 860	3 345 000
Sweden	3 373	2 754 000	2 678	2 170 000
United Kingdom	1 526	1 975 000	1 194	1 637 000
Switzerland	—	—	1 372	1 340 000
East Germany	2 774	2 384 000	—	—
South Korea	1 208	946 000	—	—
Other Countries	988	560 000	1 127	612 000
Total	314 518	299 745 000	308 868	314 530 000
Copper in slag, skimmings and sludge				
West Germany	—	—	3 599	794 000
Belgium and Luxembourg	—	—	2 898	639 000
United States	102	63 000	259	114 000
Spain	—	—	72	23 000
Total	102	63 000	6 828	1 570 000
Copper scrap (gross weight)				
United States	5 392	5 694 000	9 710	10 703 000
South Korea	2 316	2 437 000	1 909	2 187 000
Belgium and Luxembourg	980	621 000	1 876	2 066 000
Spain	1 508	1 590 000	520	551 000
United Kingdom	532	447 000	820	402 000
Japan	1 396	1 541 000	324	317 000
Italy	499	598 000	—	—

Table 1. (cont'd.)

	1975		1976^{p}	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
India	—	—	191	222 000
West Germany	2 824	3 217 000	215	215 000
Netherlands	189	224 000	144	169 000
Taiwan	261	287 000	218	95 000
Norway	—	—	54	68 000
Hong Kong	245	292 000	—	—
Other Countries	314	340 000	52	77 000
Total	16 456	17 288 000	16 033	17 072 000
Brass and bronze scrap (gross weight)				
United States	6 380	6 112 000	9 846	9 991 000
Japan	1 292	1 164 000	1 101	959 000
Italy	1 757	1 800 000	874	779 000
Belgium & Luxembourg	282	244 000	655	606 000
West Germany	560	502 000	308	300 000
France	—	—	359	297 000
India	—	—	312	283 000
Spain	242	248 000	243	213 000
South Korea	—	—	230	212 000
United Kingdom	278	331 000	239	181 000
Netherlands	631	587 000	—	—
Other Countries	708	665 000	286	238 000
Total	12 130	11 653 000	14 453	14 059 000
Copper alloy scrap, nes (gross weight)				
United States	863	867 000	1 590	1 144 000
Japan	96	91 000	382	298 000
Belgium & Luxembourg	182	131 000	110	68 000
Netherlands	87	85 000	53	55 000
Other Countries	295	181 000	129	108 000
Total	1 523	1 355 000	2 264	1 673 000
Copper refinery shapes				
United Kingdom	93 912	117 825 000	90 059	126 944 000
United States	65 182	93 506 000	86 373	126 597 000
West Germany	46 874	58 702 000	35 993	49 547 000
France	21 996	27 280 000	23 744	32 725 000
Italy	15 337	18 786 000	14 949	20 253 000
Japan	1 448	1 808 000	12 443	19 300 000
Belgium & Luxembourg	10 642	13 024 000	13 232	18 491 000
Sweden	8 828	10 822 000	12 838	17 455 000
Portugal	4 248	5 263 000	5 056	7 098 000
Switzerland	4 564	5 644 000	4 686	6 431 000
Netherlands	32 516	40 349 000	4 123	6 014 000
Brazil	4 797	6 060 000	3 129	4 269 000
South Korea	2 024	2 521 000	832	1 074 000
Taiwan	3 623	4 510 000	—	—
Other Countries	3 581	4 556 000	5 776	8 185 000
Total	319 572	410 656 000	313 233	444 383 000

Table 1. (cont'd)

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Copper bars, rods and shapes, nes				
Iran	3 748	6 732 000	3 605	6 418 000
United States	2 709	4 635 000	2 550	5 201 000
Venezuela	1 005	1 545 000	3 051	4 681 000
Pakistan	1 249	1 684 000	1 248	1 881 000
Switzerland	1 462	1 918 000	1 241	1 537 000
Dominican Rep.	815	1 143 000	769	1 155 000
Nigeria	774	1 297 000	544	866 000
Israel	—	—	524	701 000
Cuba	1 224	2 060 000	421	613 000
Malaysia	804	1 182 000	113	172 000
Other Countries	1 149	1 659 000	1 078	1 955 000
Total	14 939	23 855 000	15 144	25 180 000
Copper plates, sheet, strip and flat products				
United States	4 285	9 148 000	4 830	10 574 000
Venezuela	246	606 000	150	368 000
United Kingdom	206	377 000	—	—
Thailand	79	112 000	60	90 000
Colombia	—	—	19	44 000
New Zealand	14	51 000	2	6 000
Norway	8	20 000	—	—
Puerto Rico	5	12 000	2	7 000
Cuba	2	12 000	—	—
Other Countries	6	3 000	—	—
Total	4 851	10 341 000	5 063	11 089 000
Copper pipe and tubing				
United States	3 899	7 008 000	3 753	7 357 000
West Germany	657	1 059 000	790	1 333 000
Algeria	—	—	552	1 071 000
Israel	459	1 111 000	425	847 000
Spain	76	159 000	226	465 000
Venezuela	283	899 000	107	328 000
United Kingdom	86	188 000	34	82 000
New Zealand	183	556 000	25	75 000
Other Countries	379	936 000	522	1 152 000
Total	6 022	11 916 000	6 434	12 710 000
Copper wire and cable (not insulated)				
Pakistan	35	60 000	230	401 000
Thailand	—	—	230	366 000
United States	369	519 000	194	279 000
Switzerland	161	211 000	—	—
Bangladesh	33	55 000	—	—
Other Countries	68	176 000	21	40 000
Total	666	1 021 000	675	1 086 000

Table 1. (cont'd)

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Exports (cont'd)				
Copper alloy refinery shapes				
United States	4 885	9 635 000	7 304	14 114 000
Venezuela	170	411 000	99	230 000
Belgium and Luxembourg	20	49 000	33	82 000
Japan	354	421 000	50	63 000
New Zealand	—	—	22	54 000
Israel	274	586 000	—	—
United Kingdom	22	76 000	—	—
Bolivia	11	47 000	—	—
Other Countries	39	83 000	10	21 000
Total	5 775	11 308 000	7 518	14 564 000
Copper alloy pipe and tubing				
United States	1 225	2 499 000	2 109	4 374 000
Israel	37	98 000	42	103 000
Australia	—	—	13	52 000
United Kingdom	47	108 000	15	46 000
New Zealand	17	58 000	14	45 000
Pakistan	—	—	13	38 000
Taiwan	86	291 000	—	—
India	51	208 000	—	—
Venezuela	26	81 000	—	—
Other Countries	62	209 000	14	31 000
Total	1 551	3 552 000	2 220	4 689 000
Copper alloy wire and cable, not insulated				
United States	228	245 000	224	373 000
Australia	—	—	16	56 000
New Zealand	9	31 000	15	49 000
Colombia	45	86 000	8	16 000
South Africa	40	139 000	—	—
Other Countries	12	50 000	4	18 000
Total	334	551 000	267	512 000
Copper alloy fabricated materials, nes				
United States	574	1 166 000	551	1 531 000
United Kingdom	150	303 000	210	418 000
Japan	—	—	104	125 000
Israel	36	90 000	—	—
Thailand	46	70 000	—	—
Venezuela	15	39 000	1	5 000
Other Countries	41	88 000	33	89 000
Total	862	1 756 000	899	2 168 000

Table 1. (cont'd)

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Wire and cable insulated[2]				
United States	4 354	10 503 000	3 612	8 242 000
Iran	2 145	5 446 000	641	1 754 000
Philippines	258	359 000	748	1 746 000
Dominican Rep.	562	1 310 000	547	1 472 000
Indonesia	429	1 047 000	658	1 214 000
Turkey	435	931 000	372	855 000
Guatemala	—	—	374	797 000
Pakistan	352	439 000	249	581 000
Panama	362	955 000	271	516 000
Malta	—	—	182	463 000
Bermuda	168	372 000	149	391 000
Equador	69	195 000	70	376 000
Zaire	—	—	107	368 000
Trinidad - Tobago	435	869 000	—	—
Venezuela	280	825 000	—	—
United Kingdom	92	316 000	—	—
Other Countries	2 225	5 998 000	1 603	3 897 000
Total	12 166	29 565 000	9 583	22 672 000
Total exports of copper and products		834 625 000		887 957 000
Imports				
Copper in ores, concentrates and scrap	16 519	17 431 000	13 847	14 755 000
Copper refinery shapes	10 908	14 987 000	9 123	13 025 000
Copper bars, rods and shapes, nes	621	1 061 000	4 082	6 464 000
Copper plates, sheet strip and flat products	265	600 000	533	1 223 000
Copper pipe and tubing	3 520	6 751 000	4 127	8 918 000
Copper wire and cable, except insulated	745	1 904 000	973	2 818 000
Copper alloy scrap (gross weight)	3 728	3 408 000	4 743	4 809 000
Copper powder	283	586 000	351	767 000
Copper alloy refinery shapes, rods and sections	5 936	10 385 000	6 663	11 025 000
Brass plates, sheet and flat products	2 671	4 972 000	3 776	7 133 000
Copper alloy plates, sheet, strip and flat products	661	2 295 000	927	3 017 000
Copper alloy pipe and tubing	1 860	5 367 000	2 794	6 890 000

Table 1. (concl'd)

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Copper alloy wire and cable, except insulated	664	2 055 000	482	1 669 000
Copper and alloy fabricated material, nes	971	2 822 000	1 759	5 340 000
Insulated wire and cable	..	35 411 000	..	27 082 000
Copper oxides and hydroxides	170	241 000	239	612 000
Copper sulphate	806	361 000	1 406	681 000
Copper alloy castings	363	1 001 000	297	954 000
Total imports of copper and products	..	111 638 000	..	117 182 000
Consumption[3]				
Refined	185 195	..	206 205	..

Source: Statistics Canada.
[1]Blister copper plus recoverable copper in matte and concentrate exported. [2]Includes also small quantities of non-copper wire and cable, insulated. [3]Producers' domestic shipments, refined copper.
— Nil; pPreliminary; .. Not available; nes Not elsewhere specified.

concentrates produced in Eastern Canada. The often-postponed closure of the famous Horne mine, which finally took place in 1976, accentuated this situation.

Mining and milling were resumed late in July at the Henderson and Cedar Bay operations of Campbell Chibougamau Mines Ltd. These mines were closed in May 1975 due to low copper prices and failure to reach agreement on the terms of a new labour contract.

The depressed state of copper prices during 1976 led to decisions to close additional mines in Quebec. Sullivan Mining Group Ltd. announced its intention to close its operations at Cupra and D'Estrie in the Eastern Townships, and Madeleine Mines Ltd. stated that it will close operations at its Gaspé mine early in 1977.

Ontario. Union Minière Explorations and Mining Corporation Limited (UMEX) began operations at its new Thierry copper deposit in the Pickle Lake area of Ontario in mid-August, and commercial operating levels were reached by mid-September. Concentrates will be shipped by road and rail to Noranda, Quebec for smelting. Refining will be carried out at Noranda Mines Limited's Montreal refinery. The final cost of the project was approximately $104 million, having escalated from an estimated $45 million in 1972. Ore reserves are estimated to be 15 million tonnes, with an average grade of 1.63 per cent copper and minor amounts of nickel. This is adequate for at least 12 years of operation at the planned production rate of 1 250 000 tonnes of ore a year. Production for the first year will be from two small open-pit mines followed by production from an underground mine.

Development of the Texasgulf Inc. No. 2 underground mine at Timmins has proceeded on the original schedule and, as a result, ore-production capacity will increase to 4.5 million tonnes a year from the present 3.3 million tonnes. As average copper grades in the ore tend to increase with depth, this factor, together with the increased ore tonnage produced, should substantially increase the 1976 copper production by 1980. As a result, large tonnages of copper concentrate will continue to be available for treatment at other smelters for a number of years to come. At year-end, ore was being mined from the final bench of the open-pit mine, and the transition to underground mining was well advanced.

The prolific Timmins mining area yielded another mineral deposit late in 1975. Teck Corporation Limited announced a copper-nickel discovery 56 kilometres northwest of Timmins. The deposit was discovered by airborne geophysical methods, and subsequent diamond drilling indicated significant nickel and copper mineralization. Further drilling was planned to provide additional information on the size and grade of the deposit.

Selco Mining Corporation Limited and Moore McCormack Resources Inc. announced a major program of work for their joint venture Detour project in Brouillan Township, northwestern Quebec. The program will extend to mid-1978 at a cost of approximately $13 million and will include shaft sinking and underground examination of two copper-zinc-silver-gold deposits.

At the Annual Meeting of Shareholders, Falconbridge Nickel Mines Limited (Falconbridge) disclosed that its smelter modernization project, which was temporarily suspended in 1975, would be resumed later in 1976. The project will cost an estimated $97 million. Canadian Industries Limited has agreed to purchase the entire production of sulphuric acid from the smelter.

Table 2. Canada, copper production, trade and consumption, 1965, 1970 and 1974-76

	Production		Exports			Imports	Consumption[2]
	All Forms[1]	Refined	Ore and Matte	Refined	Total	Refined	Refined
				(tonnes)			
1965	460 725	393 827	78 922	181 277	260 199	5 213	203 824
1970	610 279	493 261	161 377	265 263	426 640	13 192	215 834
1974	821 381	559 124	344 030	285 912	629 942	22 106	247 985
1975	733 826	529 199	314 518	319 572	634 090	10 908	185 195
1976[p]	747 131	510 468	308 868	313 233	622 101	9 123	206 205

Source: Statistics Canada.
[1]Blister copper, plus recoverable copper in matte and concentrates exported. [2]Producers' domestic shipments, refined copper.
[p]Preliminary.

Mattagami Lake Mines Limited reported further progress in the development of its wholly owned Lyon Lake mine. A three-compartment shaft was sunk during the year, mine development started and commercial production is expected to begin in 1978.

Inco Limited (Inco) is both Ontario's and Canada's largest mine producer of copper. In 1976 Inco produced 156 500 tonnes of copper, compared with 165 100 tonnes in 1975. The two operating divisions in Ontario and Manitoba mined a total of 18 million tonnes with an average grade of 0.97 per cent copper. Inco had 15 mines operating in 1976, of which 12 were in Ontario. Two new mines were under development in Ontario in 1976, Levack East and the Clarabelle open-pit extension.

Manitoba. At the Ruttan mine of Sherritt Gordon Mines Limited, operating difficulties persisted throughout 1976, resulting in lagging ore production and waste removal from the open pit. It was decided that, for the rest of the operating life of the open pit, operations will be maintained on a five-day-week basis. Underground exploration of the Ruttan orebody made good progress and Sherritt decided to proceed with underground mine development down to the 1 400 level, subject to arranging the necessary financing, estimated at $30 million.

The Lynn Lake mine was closed in June. The concentrator was mothballed in the hope of locating other base metal deposits in the surrounding area.

At Inco's Manitoba Division, development work was continued at the three operating mines; Birchtree, Pipe and Thompson. Production was sharply reduced at the low-grade Pipe open-pit mine in January, but gradually increased later in the year.

British Columbia. During May 1976 the British Columbia government introduced a bill to repeal the Mineral Royalties Act. Further legislation was introduced in June which reverted to the use of profit, rather than revenue, as the basis for taxation of mining companies operating in the province. This legislation, Bill 57, imposed a tax of 17.5 per cent on the net income of operating mines effective at the beginning of the 1976 fiscal year in place of the system of royalties and escalating royalties on mineral revenue. The change was well-received by the British Columbia copper producers.

Lornex Mining Corporation Ltd. (Lornex) amended its sales agreement with Japanese copper concentrate buyers. The modified agreement provides for deliveries of undisclosed fixed amounts of copper concentrates in the years 1976-79 rather than the full production of the mine. Sales to other buyers will now be permitted. In addition to these changes Lornex also agreed to a "temporary upward adjustment" in refining charges for its Japanese buyers. The effect of these changes reflected in 1976 metal production and deliveries. Production of copper in concentrate increased from 48 625 "payable" tonnes in 1975 to 66 088 "payable" tonnes in 1976. Ore reserves at Lornex were increased as a result of a program of drilling and re-evaluation to an estimated 454 million tonnes with an average grade of 0.412 per cent copper and 0.015 per cent molybdenum.

Brenda Mines Ltd. set production records in 1976 with a progressive increase in concentrator throughput and productivity during the year. Much of the improvement in operating performance was attributed to full computer control of all grinding and flotation units in the concentrator.

Gibraltar Mines Ltd. experienced a 50 per cent reduction in its average operating rate in the first nine months of 1976 as a result of a 19-week strike by mine employees which ended July 29.

Operations at Noranda's Bell Copper mine were affected by a 29-week strike. Mineable ore reserves were increased by 1.5 million tonnes during the year to 26.6 million tonnes with an average grade of 0.486 per cent copper and 0.012 ounces of gold per ton.

Bethlehem Copper Corporation resumed a more normal stripping ratio at the Iona deposit, after temporarily reducing it in 1975 to improve the economics of the operation. A further substantial stripping program was planned for 1977 to prepare the Jersey mine for operation by 1978.

In order to minimize operating losses, Newmont Mines Limited reduced the operating rate at the Granduc mine from 4 082 tonnes a day to 3 084 tonnes a day during the second quarter. This permitted more selective mining and resulted in improved average mill head grades.

Smelters and refineries

Smelter throughput at Gaspé Copper Mines, Limited was again below the planned level in 1976. Precipitation towers in the oxide-leaching operation were under reconstruction and expected to be in operation by May 1977.

The Noranda smelting complex was short of copper concentrates in 1976. As a result, the reverberatory furnaces were occasionally placed on standby and the continuous reactor was shut down for 24 days. In order to reduce dust emissions the No. 2 reverberatory furnace was shut down for conversion to wet-charge operation and four roasters were closed down. The continuous reactor had its longest campaign life to date with a run of 180 days without shut down for refractory repairs.

Falconbridge Nickel Mines Limited reactivated its smelter modernization program in August 1976. By year-end, erection of steelwork was essentially complete and erection of pressure vessels for the acid plant was 50 per cent complete. Total expenditures in 1976 were $32 million of an estimated total cost of $97 million. Start-up of the new facilities is scheduled for early 1978.

The existing smelter operated one blast furnace and two converters during the year. Oxygen enrichment of the blast air began in February.

Hudson Bay Mining and Smelting Co., Limited has extended the operating cycle of its Flin Flon smelter. Rebricking of the reverberatory furnace now takes place once every 18 months instead of once every 12 months.

The intentions of Texasgulf Inc. (Texasgulf) for the scale and the timing of its new copper smelter and refinery, now under construction at Timmins, changed during 1976. At the end of 1975 Texasgulf intended to build facilities with a capacity of 120 000 tonnes a year of refined copper at an estimated cost of $250 million. During April it was announced that the smelter-refinery would have an initial capacity of only 60 000 tonnes a year, to be followed later by second-phase units of the same capacity. Late in 1976 it was announced that the completion date of the project may be modified in view of escalating capital costs. It is probable that commercial operating rates at the smelter-refinery complex will not be reached until 1980. At the end of 1976 construction on the new smelter and refinery was approximately 10 per cent complete. The smelter building and refinery tankhouse will be erected in 1977.

At the Fort Saskatchewan metallurgical complex, Sherritt successfully completed a pilot test of the S-C Copper Process, a joint Sherritt-Cominco Ltd. development with 50 per cent funding by the Federal Government under a Program for Advancement of Industrial Technology (PAIT) grant. The process is said to be environmentally clean and applicable to a wide range of copper sulphide concentrates. High purity copper is produced by electrowinning. Sulphur is produced as a by-product in elemental form.

Work on the Afton Mines Ltd. mine-smelter complex proceeded during the year and by year-end was on schedule and within budget. Structural steelwork on the smelter was nearing completion and about one half of the total estimated cost of the project was already spent or committed. The main office building was finished in December and deliveries of mine equipment had begun. Start up of the project is expected to be in the fall of 1977.

World supply and demand

Supply. World mine production of copper in 1976 increased to 7 954 100 tonnes, an increase of 8.7 per cent relative to 1975 production of 7 314 900 tonnes. The biggest part of this increase, 182 000 tonnes was attributable to producers in the United States who had made correspondingly large production cuts in 1975.

Production increases also occurred in almost every other copper-producing country during 1976 through increased capacity utilization or new capacity brought in.

CIPEC producers, who had instituted production and shipment cutbacks in 1975, removed these constraints in 1976, led by Chile, where full production was resumed on June 30.

In Peru the Cuajone project began production in May, and the first shipment of blister copper was made in July to the Ilo refinery. This project will produce 154 000 tonnes of copper a year when it reaches full capacity, probably in 1977, and will increase Peru's copper output by 75 per cent.

Events on the African continent threatened to become a major factor in primary copper supply in 1976. The civil war in Angola interrupted a major transportation route for Zambian and Zairian supplies and copper exports. However, alternative routes were developed and by May it was reported that all current production was being shipped. A key element in the southern African transportation system is the recently completed Tanzam railway, which now delivers Zambian copper to the Tanzanian port of Dar-es-Salaam. The potential for further violent political change in southern Africa points to a major weakness in world primary copper supply picture which could change present supply-demand projections almost at a moment's notice.

Poland's mine production of copper continued its rapid increase during 1976 to about 300 000 tonnes compared with 270 000 tonnes in 1975 and 198 000

(text continued on page 204)

Table 3. Principal copper mines in Canada 1976 and (1975)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrate Produced	Grade of Copper in Concentrate	Contained[1] Copper Produced	Destination[2] of Copper Concentrates
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/tonne)		(tonnes)	(tonnes)	(%)	(tonnes)	
Newfoundland												
ASARCO Incorporated, Buchans	1 100 (1 100)	0.96 (0.95)	10.69 (10.54)	6.03 (5.92)	– (–)	105.59 (103.88)	0.71 (0.75)	188 694 (210 466)	3 752 (4 355)	26.44 (26.91)	1 627 (1 851)	8 (8)
Consolidated Rambler Mines Limited, Ming Mine, Baie Verte	1 100 (1 100)	3.68 (3.20)	– (–)	– (–)	– (–)	21.73 (19.54)	2.61 (2.06)	187 284 (203 719)	28 264 (26 935)	23.0 (23.8)	6 512 (6 416)	2,6,11 (1)
New Brunswick												
Brunswick Mining and Smelting Corporation Limited, No. 6 and No. 12 mines, Bathurst	9 100 (9 100)	0.38 (0.40)	7.18 (7.11)	2.87 (2.95)	– (–)	68.3 (79.9)	– (–)	2 247 234 (3 109 140)	16 528 (25 207)	20.86 (20.23)	3 233 (4 772)	1 (1)
Heath Steele Mines Limited, Newcastle	3 600 (2 800)	0.99 (1.03)	4.53 (3.99)	1.85 (1.54)	– (–)	77.82 (59.31)	0.61 (0.62)	1 052 568 (988 326)	26 027 (25 468)	22.13 (22.28)	7 036 (6 756)	1,2 (1)
Nigadoo River Mines Limited, Robertville	1 000 900	0.16 (0.25)	2.63 (2.69)	2.43 (2.55)	– (–)	93.94 (117.92)	– (–)	198 698 (231 403)	398 (1 090)	20.24 (20.62)	166 (473)	8 (8)
Quebec												
Campbell Chibougamau Mines Ltd., Chibougamau (5 mines)	3 600 (3 600)	1.62 (1.31)	– (–)	– (–)	– (–)	8.6 (7.9)	2.42 (1.85)	132 996 (199 166)	8 297 (8 340)	24.20 (24.08)	2 008 (2 008)	2 (2)

Falconbridge Copper Limited,	1 400	3.09	3.44	—	—	41.5	0.82	458 447	50 224	26.56	13 339	2
Lake Dufault Division, Norbec and Millenbach mines, Noranda	(1 400)	(2.50)	(3.35)	(—)	(—)	(38.4)	(0.79)	(508 727)	(45 187)	(26.38)	(11 870)	(2)
Opemiska Division, Perry and Springer	2 700	2.01	—	—	—	12.5	0.60	947 054	75 394	..	18 166	2
mines, Chapais	(2 700)	(2.02)	(—)	(—)	(—)	(11.3)	(0.48)	(863 640)	(68 946)	(..)	(16 783)	(2)
Gaspé Copper Mines, Limited,	30 600	0.53	—	—	—	..	..	11 139 325	213 720	23.75	45 493	1
Needle Mountain and Copper Mountain mines, Murdochville	(30 600)	(0.52)	(—)	(—)	(—)	(4.1)	(0.07)	(9 972 780)	(186 207)	(23.69)	(42 178)	(1)
Icon Sullivan Joint Venture,	—	—	—	—	—	—	—	—	—	—	—	—
Chibougamau	(500)	(3.26)	(—)	(—)	(—)	(..)	(0.6)	(36 512)	(4 248)	(26.95)	(1 145)	(2)
Joutel Copper Mines	—	—	—	—	—	—	—	—	—	—	—	—
Limited, Joutel	(600)	(1.80)	(6.13)	(—)	(—)	(—)	(—)	(3 355)	(..)	(25.84)	(85)	(2)
Madeline Mines Ltd., St. Anne des Monts	2 300	1.07	—	—	—	..	—	738 398	..	33.20	7 391	1
	(2 300)	(1.15)	(—)	(—)	(—)	(6.9)	(—)	(823 928)	(26 461)	(33.18)	(8 779)	(1)
Mattagami Lake Mines Limited,	3 500	0.55	7.3	0.10	—	31.9	0.48	1 112 156	18 633	24.2	5 175	2
Matagami	(3 500)	(0.62)	(7.3)	(—)	(—)	(29.5)	(0.48)	(1 166 372)	(22 573)	(24.11)	6 149	(2)
Noranda Mines Limited,	1 900	1.40	—	—	—	14.1	4.35	123 746	23 292	6.98	1 626	2
Horne Division	(1 900)	(2.15)	(—)	(—)	(—)	(..)	(4.62)	(312 344)	(87 725)	(25.91)	(22 740)	(2)
Normetal Mines Limited,	—	—	—	—	—	—	—	—	—	—	—	—
Normetal	(900)	(0.58)	(5.86)	(—)	(—)	(43.9)	(0.5)	(74 525)	(1 578)	(23.07)	(355)	(2)

Table 3. (cont'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrate Produced	Grade of Copper in Concentrate	Contained[1] Copper Produced	Destination[2] of Copper Concentrates
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/tonne)		(tonnes)	(tonnes)	(%)	(tonnes)	
Quebec (cont'd)												
Orchan Mines Limited, Orchan and Garon Lake mines, Matagami	1 700 (1 700)	0.78 (1.19)	6.74 (4.65)	— (—)	— (—)	31.9 (16.5)	0.51 (0.31)	424 260 (382 655)	9 933 (15 174)	25.04 (25.53)	2 487 (3 875)	2 (2)
Patino Mines (Quebec) Limited Copper Rand, Copper Cliff and Portage mines, Chibougamau	2 500 (2 500)	1.72 (1.67)	— (—)	— (—)	— (—)	10.3 (8.6)	3.08 (1.95)	516 356 (398 721)	34 508 (25 492)	24.03 (24.91)	8 293 (6 350)	2 (2)
Rio Algom Limited, Mines de Poirier, Joutel	— (1 600)	— (2.43)	— (—)	— (—)	— (—)	— (..)	— (..)	— (200 267)	— (17 591)	— (26.24)	— (4 611)	— (2)
Sullivan Mining Group Ltd., Cupra Division, Stratford Centre	1 300 (1 300)	.. (2.24)	.. (4.12)	.. (0.47)	.. (—)	.. (33.3)	.. (0.45)	.. (50 855)	.. (3 794)	.. (28.08)	.. (1 077)	.. (10,11)
D'Estrie Mining Company Ltd.	— (—)	.. (2.57)	.. (2.12)	.. (0.54)	.. (—)	.. (38.3)	.. (0.51)	.. (163 379)	.. (13 942)	.. (28.06)	.. (3 954)	.. (10,11)
Clinton Copper Mines Ltd.	— (—)	.. (2.59)	.. (2.49)	.. (0.47)	.. (—)	.. (30.0)	.. (0.44)	.. (66 710)	.. (6 466)	.. (24.10)	.. (1 568)	.. (10,11)
Union Minière Exploration, Thierry Mine, Pickle Lake	3 600 (—)	1.14 (—)	— (—)	— (—)	0.10 (—)	7.5 (—)	.. (—)	230 608 (—)	9 541 (—)	24.80 (—)	2 366 (—)	2 (—)

Ontario

Falconbridge Nickel Mines Limited,	12 700	..	—	—	..	..	..	2 920 555	..	..	15 457[3]	4
East, Falconbridge, Fecunis, Hardy Open-pit, Longvac South, North, Onaping and Strathcona mines, Sudbury	(11 200)	(..)	(—)	(—)	(..)	(..)	(..)	(2 732 446)	(..)	(..)	(18 468)[3]	(4)
Falconbridge Copper Limited,	1 100	2.15	9.57	1.23	—	183.8	0.55	377 257	28 499	22.42	6 390	2
Sturgeon Lake Joint Venture, Sturgeon Lake	(1 100)	(2.78)	(9.07)	(1.17)	(—)	(182.0)	(0.61)	(341 720)	(28 424)	(24.58)	(6 987)	(2)
Inco Limited, Clarabelle,	61 200	1.13	—	—	1.33	..	..	14 949 699	..	..	161 474[3]	3
Coleman, Copper Cliff North, Copper Cliff South, Creighton, Frood Stobie, Garson, Kirkwood, Levack, Little Stobie, MacLennan, Victoria and Crean Hill mines, Sudbury Shebandowan Mine, Shebandowan	(61 700)	(1.09)	—	—	(1.29)	(..)	(..)	(15 593 570)	(..)	(..)	(151 749)[3]	(3)
Kanichee Mining Incorporated,	500	..	—	—	..	—	—	5 213	..	6.96	31	4
Temagami	(500)	(0.72)	(—)	(—)	(0.50)	(—)	(—)	(136 138)	(..)	(7.98)	(822)	(4)
Mattabi Mines Limited, Sturgeon Lake	2 700	1.23	8.13	0.76	—	121.0	..	966 798	37 738	26.20	9 963	2
	(2 700)	(0.97)	(7.34)	(0.70)	(—)	(110.7)	(..)	(975 154)	(33 566)	(23.52)	(7 844)	(2)
Noranda Mines Limited,	4 500	1.69	2.55	0.12	—	44.2	0.17	1 529 781	88 875	27.01	24 530	..
Geco Division, Manitouwadge	(4 500)	(1.84)	(3.54)	(0.20)	(—)	(49.4)	(—)	(1 450 891)	(93 017)	(26.69)	(25 521)	(2)

Table 3. (cont'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrate Produced	Grade of Copper in Concentrate	Contained[1] Copper Produced	Destination[2] of Copper Concentrates
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/tonne)		(tonnes)	(tonnes)	(%)	(tonnes)	
Ontario (cont'd)												
Pamour Porcupine Mines Limited, Schumacher Division, Schumacher	2 700 (2 700)	.. (0.62)	— (—)	— (—)	— (—)	.. (3.8)	.. (0.93)	846 504 (621 131)	11 274 (11 666)	25.43 (30.33)	2 867 (3 538)	2 (2)
Selco Mining Corporation Limited, South Bay Mine, Uchi Lake	500 (500)	1.73 (1.82)	10.38 (11.18)	— (—)	— (—)	79.9 (93.6)	— (—)	163 482 (152 710)	9 387 (9 323)	26.28 (26.32)	2 504 (2 454)	2 (2)
Teck Corporation Limited, Silverfields Mining Division, Cobalt District	200 (200)	0.5 (0.4)	— (—)	— (—)	0.2 (—)	246.8 (332.6)	— (—)	69 989 (43 918)	18 (4)	.. (5.3)	.. (..)	.. (2)
Texasgulf Inc., Kidd Creek Mine, Timmins	9 100 (9 100)	1.74 (1.71)	8.05 (8.20)	0.30 (0.25)	— (—)	119.7 (106.3)	— (—)	3 242 279 (3 293 288)	206 657 (216 324)	23.95 (23.35)	51 921 (54 119)	2 (2)
Willroy Mines Limited, Manitouwadge Division, Manitouwadge	1 500 (1 500)	0.56 (0.42)	3.67 (3.82)	0.17 (0.22)	— (—)	54.5 (53.5)	— (—)	311 431 (296 970)	6 422 (3 915)	26.20 (24.79)	1 614 (971)	2 (2)
Manitoba												
Dumbarton Mines Limited, Maskwa East and West Extensions, Bird River	— (—)	0.29 (0.24)	— (—)	— (—)	1.04 (1.11)	— (—)	— (—)	128 111 (323 602)	— (—)	— (—)	338 (646)	4 (11)

Falconbridge Nickel	900	..	—	—	..	..	—	188 994	..[4]	..	..	3,4
Mines Limited,	(900)	(..)	(—)	(—)	(..)	(..)	(—)	(171 274)	(..)[4]	(..)	(..)	(3,4)
Manibridge Mine,												
Wabowden												
Hudson Bay Mining												
and Smelting Co.,	7 700	2.3	2.7	0.2	—	20.6	1.37	1 417 617	174 670	17.02	30 173	6
Limited,	(7 700)	(2.40)	(3.00)	(0.20)	(—)	(20.6)	(1.02)	(1 333 706)	(179 902)	(16.48)	(30 100)	(6)
Anderson, Chisel Lake, Dickstone, Flin Flon, Ghost, Osborne, Schist, Stall Lake, White Lake and Centennial mines, Flin Flon and Snow Lake												
Inco Limited,												
Birch, Pipe and	16 700	..	—	—	..	—	—	2 751 947	..[5]	..	..	3
Thompson mines,	(16 700)	(..)	(—)	(—)	(..)	(—)	(—)	(3 417 552)	(..)[5]	(..)	(..)	(3)
Thompson												
Sherritt Gordon Mines Limited,												
Farley Mine	3 600	0.42	—	—	0.97	—	—	178 979	1 440	28.88	698	6
Lynn Lake	(3 600)	(0.38)	(—)	(—)	(0.84)	(—)	(—)	(318 908)	(1 776)	(30.24)	(1 028)	(6)
Fox Mine	2 700	1.56	1.68	—	—	—	—	755 123	43 412	25.32	11 148	6
Lynn Lake	(2 700)	(1.74)	(1.81)	(—)	(—)	(—)	(—)	(913 702)	(59 724)	(23.92)	(14 515)	(6,9)
Ruttan Mine	9 100	1.08	2.14	—	—	..	..	2 413 870	92 218	24.63	23 729	2,6,7
Ruttan Lake	(9 100)	(0.96)	(1.90)	(—)	(—)	(..)	(..)	(3 030 721)	(103 728)	(24.02)	(25 789)	(2)
British Columbia												
Bethlehem Copper												
Corporation	18 100	0.444	—	—	—	..	..	6 763 881	68 066	36.74	25 003	9
Heustis Mine	(18 100)	(0.474)	(—)	(—)	(—)	(0.7)	(..)	5 864 538	(74 971)	(33.05)	(24 780)	(9)
Highland Valley												
Brenda Mines Ltd.,												
Peachland	21 800	0.167	—	—	—	..	..	10 047 627	51 855	28.08	14 563	2
	(21 800)	(0.188)	(—)	(—)	(—)	(..)	(..)	(9 115 898)	(52 315)	(28.87)	(15 101)	(8,9,2)

Table 3. (cont'd)

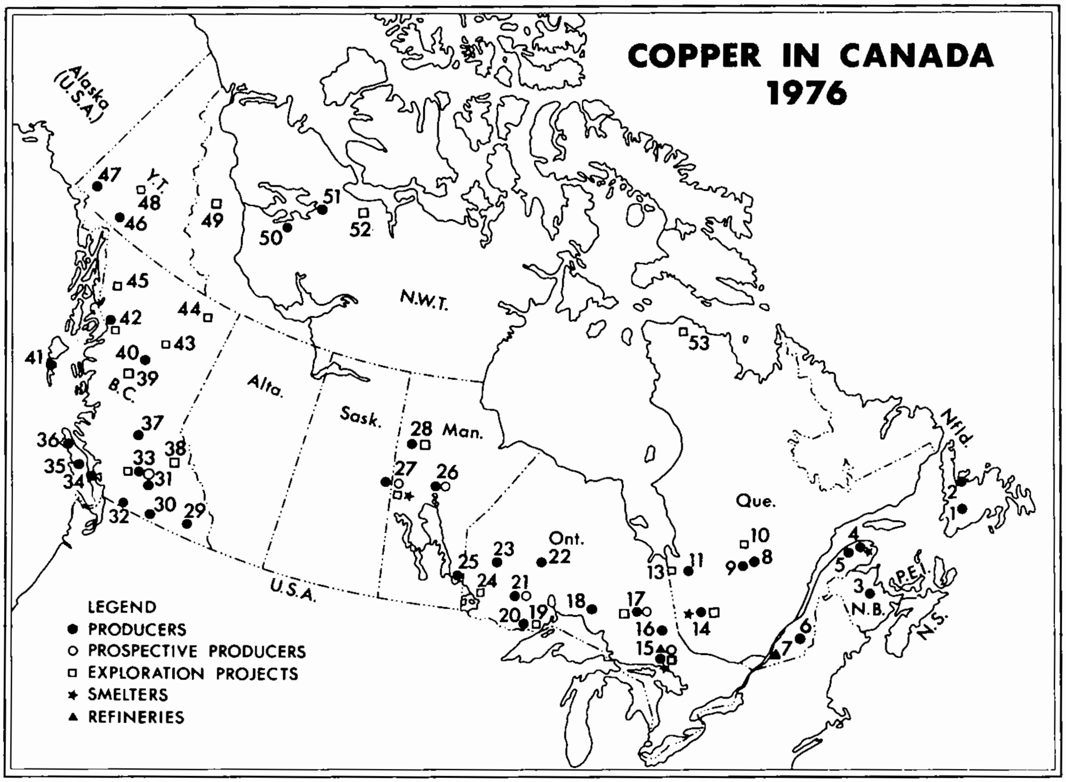
Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrate Produced	Grade of Copper in Concentrate	Contained[1] Copper Produced	Destination[2] of Copper Concentrates
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/tonne)		(tonnes)	(tonnes)	(%)	(tonnes)	
British Columbia (cont'd)												
Consolidated Churchill Copper Corporation Ltd.,	—	—	—	—	—	—	—	—	—	—	—	—
Magnum Mine, Fort Nelson	(800)	(3.51)	(—)	(—)	(—)	(..)	(..)	(44 394)	(4 971)	(30.49)	(1 515)	(..)
Craigmont Mines Limited,	4 900	1.29	—	—	—	—	—	1 763 569	76 411	28.6	21 827	9
Merritt	(4 800)	(1.45)	(—)	(—)	(—)	(—)	(—)	(1 774 742)	(84 172)	(29.39)	(24 734)	(8,9,3)
Falconbridge Nickel Mines Ltd., Wesfrob Mines Limited,	5 300	..	—	—	—	..	..	..	11 960	19.9	2 380	9
Tasu Mine, Tasu Harbour, Q.C.I.	(5 300)	(0.212)	(—)	(—)	(—)	(..)	(..)	(1 622 396)	(8 039)	(19.60)	(1 542)	(9)
Gibraltar Mines Ltd., (N.P.L.),	36 300	0.45	—	—	—	—	—	7 672 345	111 090	26.0	28 883	..
McLeese Lake, Caribou District	(36 300)	(0.431)	(—)	(—)	(—)	(—)	(—)	(10 387 278)	(144 042)	(26.31)	(37 902)	(9)
Granby Mining Corporation,	12 700	0.42	—	—	—	2.1	0.2	4 008 247	45 483	32.36	13 913	9,10
Granisle Mine, Babine Lake	(11 800)	(0.436)	(—)	(—)	(—)	(1.3)	(0.13)	(4 475 131)	(..)	(..)	(17 866)	(9,10)
Phoenix Copper Div., Greenwood	2 600	0.50	—	—	—	6.2	0.6	965 851	15 435	27.43	4 232	8
	(2 600)	(0.487)	(—)	(—)	(—)	(6.0)	(0.6)	(985 881)	(15 671)	(..)	(4 201)	(8)

Newmont Mines Limited Granduc Mine, Stewart	6 800 (6 800)	1.26 (1.20)	— (—)	— (—)	— (—)	.. (..)	.. (..)	1 315 914 (1 499 578)	54 107 (59 242)	.. (28.58)	15 670 (16 935)	8,9 (8,9)
Lornex Mining Corporation Ltd., Lornex Mine, Highland Valley	40 800 (40 800)	0.511 (0.495)	— (—)	— (—)	— (—)	.. (..)	.. (..)	15 436 996 (11 696 489)	204 021 (154 269)	33.48 (32.66)	66 094[6] (48 602)[6]	8,9,11 (8,9)
Noranda Mines Limited, Bell Copper Division, Babine Lake	9 100 (9 100)	0.429 (0.456)	— (—)	— (—)	— (—)	.. (..)	0.34 (..)	1 925 259 (4 335 076)	25 749 (63 283)	25.83 (26.02)	6 639 (16 465)	2 (2)
Similkameen Mining Company Limited, Ingerbelle Pit, Princeton	20 000 (13 600)	0.42 (0.46)	— (—)	— (—)	— (—)	.. (0.7)	.. (..)	6 355 743 (3 694 061)	84 567 (53 466)	.. (27.6)	23 133 (14 760)	8,9 (8,9)
Texada Mines Ltd., Vanada	4 100 (4 100)	0.24 (0.292)	— (—)	— (—)	— (—)	2.2 (1.7)	0.07 (0.05)	848 483 (929 985)	5 673 (8 290)	21.07 (21.51)	1 195 (1 604)	9 (9)
Utah Mines Ltd., Island Copper Mine, Coal Harbour V.I.	34 500 (34 500)	0.47 (0.48)	— (—)	— (—)	— (—)	.. (..)	.. (..)	12 247 000 (12 065 572)	214 459 (211 374)	23.0 (24.0)	48 988 (50 239)	9 (9)
Western Mines Limited, Lynx and Myra mines, Buttle Lake, V.I.	700 (1 000)	1.19 (1.12)	(7.73) (7.59)	1.42 (1.42)	— (—)	169.3 (153.9)	3.08 (2.74)	269 294 (260 719)	9 012 (8 053)	27.74 (28.30)	2 953 (2 712)	9 (9)
Yukon Territory												
Whitehorse Copper Mines Ltd., Little Chief Mine, Whitehorse	2 300 (2 200)	1.69 (1.52)	— (—)	— (—)	— (—)	.. (..)	.. (..)	726 507 (669 559)	26 937 (25 082)	41.05 (36.16)	11 051 (9 100)	6 (6)

Table 3. (concl'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Milles: Copper	Zinc	Lead	Nickel	Silver	Gold	Ore Milled	Copper Concentrate Produced	Grade of Copper in Concentrate	Contained[1] Copper Produced	Destination[2] of Copper Concentrates
	(tonnes ore/day)	(%)	(%)	(%)	(%)	(gms/tonne)		(tonnes)	(tonnes)	(%)	(tonnes)	
Northwest Territories												
Echo Bay Mines Ltd.												
Port Radium	100	..	—	—	—	..	—	35 731	2 407	16.0	398	8
	(100)	(..)	(—)	(—)	(—)	(..)	(—)	(28 350)	(1 969)	(17.70)	(362)	(8)
Terra Mining and Exploration Ltd.,												
Silver Bear Mine	200	0.2	..	..	..	1 491.4	—	41 812	..	..	64	..
Great Slave Lake	(200)	(..)	(—)	(—)	(—)	..	—	(38 901)	(..)	(..)	(49)	(..)

Sources: Company reports and technical press.
[1]Total copper in concentrates. [2]Destination of concentrates: 1, Gaspé Copper Mines Limited; 2, Noranda Mines Limited; 3 Inco, Sudbury; 4, Falconbridge Nickel, Sudbury; 5, Falconbridge Nickel, Norway; 6, Hudson Bay Mining and Smelting Co. Ltd.;7, Sherritt Gordon Mines Ltd.; 8, United States; 9, Japan; 10, Germany; 11, Unspecified and other countries. [3]Derived from deliveries not reported directly. [4]Included in the Sudbury total for Falconbridge Nickel Mines Limited. [5]Included in the Copper Cliff total for Inco. [6]Payable copper only.
— Nil; .. Not available.



Producers

(numbers correspond to those on the map)

1. ASARCO Incorporated
2. Consolidated Rambler Mines Limited
3. Brunswick Mining and Smelting Corporation Limited (No. 6 and No. 12 mines)
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
4. Gaspé Copper Mines, Limited
5. Madeleine Mines Ltd.
6. Sullivan Mining Group Ltd. (Cupra, d'Estrie, Clinton Mines)
   Bouzan Joint Venture
8. Campbell Chibougamau Mines Ltd. (Cedar Bay, Henderson, Main, Grandroy, Gwillim mines)
   Icon Sullivan Joint Venture
   Patino Mines (Quebec) Limited (Copper Rand, Copper Cliff, Portage, Lemoine mines)
9. Falconbridge Copper Limited, Opemiska Division (Perry, Springer, Cooke mines)
11. Mattagami Lake Mines Limited
    Orchan Mines Limited (Orchan, Norita mines)
14. Falconbridge Copper Limited, Lake Dufault Division (Norbec, Millenbach mines)
    Noranda Mines Limited (Horne mine)
15. Falconbridge Nickel Mines Limited (East, Falconbridge, Fecunis, Hardy, Longvack South, North, Onaping, Strathcona mines)
    Inco Limited (Coleman, Copper Cliff North, Copper Cliff South, Creighton, Frood Stobie, Garson, Levack, Levack West, Little Stobie, Victoria, Crean Hills mines)
16. Kanichee Mining Incorporated
17. Texasgulf Inc. (Kidd Creek mine)
    Pamour Porcupine Mines, Limited
18. Noranda Mines Limited, Geco Division
    Willroy Mines Limited (Willecho, Willroy mines)
20. Inco (Shebandowan)
21. Sturgeon Lake Mines Limited
    Mattabi Mines Limited
22. Union Miniere Explorations and Mining Corporation Limited (Thierry mine)
23. Selco Mining Corporation Limited, South Bay Division
25. Dumbarton Mines Limited
26. Falconbridge Nickel Mines Limited (Manibridge mine)
    Inco (Birchtree, Pipe and Thompson mines)
27. Hudson Bay Mining and Smelting Co., Limited (Anderson, Chisel, Flin Flon, Ghost, Osborne, Schist, Stall, White Lake mines)

28. Sherritt Gordon Mines Limited (Farley, Fox and Ruttan mines)
30. Granby Mining Corporation, Phoenix Copper Division
31. Brenda Mines Ltd.
32. Similkameen Mining Company Limited (Ingerbelle and Similkameen deposits)
33. Bethlehem Copper Corporation (Huestis, Iona and Jersey mines)
    Lornex Mining Corporation Ltd.
    Craigmont Mines Limited
34. Texada Mines Ltd.
35. Western Mines Limited (Lynx, Myra mines)
36. Utah Mines Ltd. (Island Copper mine)
37. Gibraltar Mines Ltd.
40. Granby Mining Corporation (Granisle mine)
    Noranda Mines Limited, Bell Copper Division
41. Falconbridge Nickel Mines Limited (Wesfrob mine)
42. Newmont Mines Limited
46. Whitehorse Copper Mines Ltd. (Little Chief mine)
50. Terra Mining and Exploration Limited
51. Echo Bay Mines Ltd.

Prospective producers

3. Brunswick Mining and Smelting Corporation Limited (No. 12 mine)
15. Falconbridge Nickel Mines Limited (Thayer Lindsay mine)
    Inco (Murray, Totten, Levack East, Clarabelle mines)
17. Texasgulf Inc. (Kidd Creek No. 2 mine)
21. Mattagami Lake Mines Limited (Lyon Lake Division)
26. Inco (Soab mine)
27. Hudson Bay Mining and Smelting Co., Limited (Centennial, Westarm mines)
33. Afton Mines Ltd. (Kamloops)

Exploration projects

10. Selco Mining Corporation Limited and Muscocho Explorations Limited
13. Selco Mining Corporation/Moore McCormack Resources Inc. (Detour Project)
14. Falconbridge Copper Limited (Lake Dufault Division)
    Noranda Mines Limited (Magusi River property)
15. Falconbridge Nickel Mines Limited (Craig, Onex mines)
    Inco (Cryderman, Whistle mine)
17. Teck Corporation Limited (Montcalm township)
19. Great Lakes Nickel Limited
27. Hudson Bay Mining and Smelting Co., Limited (Hudvam, Rail, Reed, Wim mines, Lost Lake deposit)
    Stall Lake Mines Limited
28. Sherritt Gordon Mines Limited (Lynn Lake)
33. Bethlehem Copper Corporation (J-A, Maggie, Lake and Iona zones)
    Highmont Mining Corp. Ltd.
    Leemac Mines Ltd.
    Valley Copper Mines Limited
38. Noranda Mines Limited (Goldstream River)
39. Equity Mining Corporation (Sam Goosly)
42. Consolidated Citex Resources Inc.
43. Falconbridge Nickel Mines Limited (Sustut deposit)
44. Davis-Keays Mining Co. Ltd.
45. Liard Copper Mines Ltd.
    Stikine Copper Limited
    Texasgulf Inc. (Red Group)
48. Silver Standard Mines Limited and Asarco Exploration Company of Canada, Limited
    United Keno Hill Mines Limited
    Falconbridge Nickel Mines Limited
    Canadian Superior Exploration Limited
49. Shell Canada Limited (Coates Lake)
52. Texasgulf Inc. (Izok Lake)
53. New Quebec Raglan Mines Limited

Smelters

4. Gaspé Copper Mines, Limited
14. Noranda Mines Limited
15. Falconbridge Nickel Mines Limited, Inco Limited
27. Hudson Bay Mining and Smelting Co., Limited

Refineries

7. Canadian Copper Refiners Limited
15. Inco Limited

Table 4. Prospective[1] copper producers

Company and Location	Mill Capacity[2] and Ore Grade	Year Production Expected	Destination of Copper Concentrates	Remarks
New Brunswick				
Brunswick Mining and Smelting Corporation Limited, No. 12 Mine, Bathurst	10 000 Cu 0.30 Pb 3.79 Zn 9.22	1979	Murdochville, Noranda	Expanding No. 12 mine to 10 000 tpd from 6 400. Development includes new 8 m shaft.
Quebec				
Orchan Mines Limited, La Gauchetiere Township	700 Zn 4.5 Cu 0.9 Ag 17.14 gms/tonne	1978	Noranda	Deposit acquired from Phelps Dodge Corporation of Canada. Will be developed by decline and 550 m vertical shaft.
Ontario				
Texasgulf Inc., Kidd Creek No. 2 Mine, Timmins	12 700 Cu 2.70 Zn 5.92 Pb 0.21 Ag 79.19 gms/tonne	1978	Timmins	Building a 59 000 tpy copper smelter/refinery by 1978-79. Mine production to be expanded to 4.5 million tpy by 1978.
Falconbridge Nickel Mines, Thayer Lindsay Mine, Falconbridge	— Cu .. Ni ..		Falconbridge	
East Mine,	—	..	Falconbridge	On standby.
Onaping Mine,	Cu ..	..	Falconbridge	On standby.
Longvack South Mine, Sudbury	Ni ..	..	Falconbridge	On standby.
Inco,	—			
Murray mine	Cu ..	..	Copper Cliff	On standby.
Totten mine	Ni ..	..	Copper Cliff	On standby.
Levack East Sudbury		1984	Copper Cliff	New mine.
Manitoba				
Hudson Bay Mining and Smelting Co., Limited, Centennial Mine, Flin Flon	— Cu 2.06 Zn 2.60	1977	Flin Flon	4 346 m of lateral development completed and crusher installation begun by end of 1976.
Westarm Mine, Schist Lake	Cu 4.63	1977	Flin Flon	Shaft completed at 580 m and extensive mine development in 1976.
Inco, Soab mine, Thompson	— Cu .. Ni ..	..	Thomspon	On standby.
British Columbia				
Afton Mines Ltd., Kamloops	6 400 Cu 1.0	1978	Kamloops	New open-pit mine and smelter operation.

Sources: Company reports and technical press.
[1]Only mines with announced production plans. [2]Mill capacity in tonnes a day of ore.
— Nil; .. Not available.

Table 5. Copper exploration projects

Company and Location	Indicated Ore Tonnage	Grade of Ore	Remarks
	(tonnes)	(%, gms/tonne)	
Quebec			
Selco Mining Corporation Limited and Muscocho Explorations Limited, Frotet Lake	1 328 000	Cu 1.73 Zn 2.96	
Selco Mining Corporation Limited and Pickands Mather, (Detour Project), Al Zone	32 114 000	Cu 0.39 Zn 2.30 Ag 35.65 Au 0.31	Near-surface deposit Underground exploration program of two zones costing $13 million begun in 1976.
B Zone	3 062 000	Cu 4.49 Zn 0.80 Ag 39.42	
Brouillan Township			
Noranda Mines Limited, Magusi River property, Noranda	1 407 000	Cu 1.2 Zn 3.5 Ag 30.85 Au 1.03	
New Quebec Raglan Mines Limited, Wakeham Bay	14 560 000	Cu 0.71 Ni 2.58	Inactive during 1976.
Ontario			
Falconbridge Nickel Mines Limited,			
Onex shaft	—	—	Development deferred.
Fraser shaft	—	—	Development reactivated in 1976.
Craig mine	—	—	Orebody being delineated by drilling in 1975.
Sudbury			
Great Lakes Nickel Limited, Pardee Township	29 756 000	Cu 0.36 Ni 0.20	Mining plans deferred.
Inco,			
Cryderman Mine,	—	—	
Whistle Mine,	—	—	
Sudbury area			
Teck Corporation Limited, Montcalm Township	—	cu .. Ni ..	Further exploration to be carried out in 1977.

Table 5 (cont'd)

Company and Location	Indicated Ore Tonnage	Grade of Ore	Remarks
	(tonnes)	(%, gms/tonne)	
Manitoba			
Hudson Bay Mining and Smelting Co., Limited,			
Flin Flon and Snow Lake,			
Hudvam Mine	363 000	Cu 1.50 Zn 1.70	
Lost Lake deposit	224 000	Cu 1.45	
Rail Lake Mine	295 000	Cu 3.00	
Reed Lake Mine	1 361 000	Cu 2.09	
Wim Mine	989 000	Cu 2.91	
Stall Lake Mines Limited, Snow Lake	610 000	Cu 5.38 Zn 2.28	
British Columbia			
Bethlehem Copper Corporation,			
J/A zone	259 709 000	Cu 0.43 Mo 0.017	Proven reserves.
Lake zone	172 365 000	Cu 0.48	Proven reserves.
Maggie zone,	181 437 000	Cu 0.40	Drill indicated. (Cu equivalent)
Highland Valley area			
Davis-Keays Mining Co. Ltd., Fort Nelson	1 247 000	Cu 3.38	
Equity Mining Corporation Sam Goosly deposit	39 463 000	Cu 0.33 Ag 95.30 Au 0.89	35 km south of Houston.
Falconbridge Nickel Mines Limited Sustut Peak	—	Cu 1.25	Amenable to open-pit mining.
Highmont Mining Corp. Ltd., Highland Valley	131 542 000	Cu 0.27 MoS_2 0.045	
Leemac Mines Ltd., Trojan property, Highland Valley	..	Cu 1.56	
Liard Copper Mines Ltd., Schaft Creek	272 156 000	Cu 0.40 MoS_2 0.036	
Noranda Exploration Company, Limited, Gold Stream River	3 175 000	Cu 4.49 Zn 3.24 Ag 23.31	83 km north of Revelstoke, B.C. Undergoing feasibility study.
Stikine Copper Limited, Stikine River area	53 524 000 71 668 000	Cu 1.20 Cu 1.00	
Texasgulf Inc., Red Group prospect	41 005 000	Cu 0.56 Au 0.34	160 km north of Stewart.
Valley Copper Mines Limited, Highland Valley	166 000 tonnes per vertical m	Cu 0.48	

Table 5. (concl'd)

Company and Location	Indicated Ore Tonnage	Grade of Ore	Remarks
	(tonnes)	(%, gms/tonne)	
Yukon Territory			
Silver Standard Mines Limited and Asarco Exploration Company of Canada, Limited, Minto Property Carmacks	4 718 000	Cu 1.8	Property developed to the feasibility study stage in 1974.
United Keno Hill Mines Limited, Falconbridge Nickel Mines Limited and Canadian Superior Exploration Limited, DEF project		Cu ..	Feasibility study completed in 1976.
Northwest Territories			
Shell Canada Limited, Coates Lake	—	Cu .. Ag ..	High grade copper mineralization has been encountered in exploration drilling.
Texasgulf Inc. Izok Lake	11 022 000	Cu 2.8 Zn 13.77 Pb 1.4 Ag 70.27	Further drilling planned for 1977.

Sources: Company reports and technical press.
— Nil; .. Not available.

Table 6. Canadian copper and copper-nickel smelters, 1976

Company and Location	Product	Rated Annual Capacity	Remarks	Ore and Concentrate Treated	Blister or Anode Copper Produced
		(tonnes)		(tonnes)	(tonnes)
Falconbridge Nickel Mines Limited, Falconbridge, Ontario	Copper-nickel matte	590 000[2]	A smelter modernization program was begun in 1975. Construction is expected to be completed in the spring of 1978. One-third of the estimated $95 million cost had been spent to the end of 1976. Fluid-bed roasters and electric furnaces will replace existing smelting equipment and a 1 180-tonne-a-day sulphuric acid plant will treat roaster gases. Refining of copper-nickel matte is carried out in Norway. In 1976 oxygen enrichment of blast furnace air permitted a one-furnace, two-converter operation throughout the year.	..	15 500[1]
Gaspé Copper Mines, Limited, Murdochville, Que.	Copper anodes	336 000[2]	Mine and smelter expansion program was completed but had start-up problems in 1974. As part of the program, a fluid-bed concentrate roaster, a 272 000-tonne-a-year sulphuric acid plant and plant water recycling facility were added to facilities previously described. Smelter is fed with Gaspé and custom concentrates.	293 700; of which 83 300 were custom concentrates	66 800
Hudson Bay Mining and Smelting Co., Limited Flin Flon, Manitoba	Blister-copper cakes	522 000[2]	Roasting furnaces, 1 reverberatory furnace, 3 converters. Treats own and custom copper concentrates, along with zinc plant residues, in conjunction with slag-fuming furnaces. A new flue system was completed, including an 825-foot stack. Campaign life in the furnaces extended from 12 to 18 months in 1976.	326 200; of which 99 000 were purchased concentrates	56 300

Table 6. (concl'd)

Company and Location	Product	Rated Annual Capacity	Remarks	Ore and Concentrate Treated	Blister or Anode Copper Produced
		(tonnes)		(tonnes)	(tonnes)
Inco Limited	Blister copper, nickel sulphide and nickel sinter for company's refineries; nickel oxide sinter for market, soluble nickel oxide for market	3 630 000[2]	Oxygen flash-smelting of copper sulphide concentrate; converters for production of blister copper. Roasters, reverberatory furnaces for smelting of copper-nickel ore and concentrate; converters for production of copper-nickel Bessemer matte. Production of matte followed by matte treatment, flotation, separation of copper and nickel sulphides, then by sintering to make sintered-nickel products for refining and marketing. Electric-furnace melting of copper sulphide and conversion of blister copper. Also custom smelting.		156 500
Noranda Mines Limited, Noranda, Que.	Copper anodes	1 542 000[3]	Roasting furnaces, 2 hot-charge and 1 green-charge reverberatory furnaces; 5 converters; 1 continuous reactor; one 85-tonne-a-day oxygen plant to supply oxygen-enriched blast. Continuous reactor was modified to produce matte instead of metal.	1 159 400; of which 724 800 were custom concentrates	207 700

Sources: Company reports.
[1]Deliveries. [2]Ores and concentrates. [3]Ores, concentrates and scrap.

Table 7. Copper refineries in Canada, 1976

Company and Location	Rated Annual Capacity	Output	Remarks
	(tonnes)	(tonnes)	
Canadian Copper Refiners Limited, Montreal East, Quebec	435 000	351 100	Refines anodes from Noranda and Gaspé smelters, blister copper from Flin Flon smelters, and purchased scrap. Copper and nickel sulphate recovered by vacuum evaporation. Precious metals, selenium and tellerium recovered from anode slimes. Produces C.C.R. brand electrolytic copper wirebars, ingot bars, ingots, cathodes, cakes and billets. Start-up of semi-continuous casting of cakes and billets was deferred.
Inco Limited Copper Refining Division, Copper Cliff, Ontario	192 000	156 500	Refines blister copper from Copper Cliff smelter. Precious metals, selenium and tellurium are recovered from anode slimes. Recovers and electrowins copper from Copper Cliff nickel refinery residue. Produces ORC brand electrolytic copper, cathodes, wirebars, cakes, billets, ingots and ingot bars.

Sources: Company reports.

tonnes in 1974. It is expected that by 1980 production will have increased to 400 000 tonnes a year. Late in 1976 West German firms signed an 8-year agreement to import 40 000 tonnes a year of Polish copper wirebars and cathode.

Expansion of capacity has continued in the Republic of Chile in spite of the reduction in copper production in 1975. Production in 1977 could be close to 1 million tonnes.

In Japan the rate at which smelters could increase their capacity utilization in 1976 in response to rising copper consumption was limited by the poor demand for sulphuric acid and by the capacity of the acid storage system.

In the United States preparations began in December for the labour union negotiations with the major copper producers in 1977. Contracts with Phelps Dodge Corporation, Magma Copper Company, ASARCO Incorporated and Kennecott Copper Corporation expire on June 30, 1977. Contracts with other producers such as Duval Corporation, Anamax Mining Company and Cyprus Mines Corporation expire between July and September. The present contracts began in mid-1974. These negotiations will have a powerful effect upon copper market psychology during the first half of 1977. Should a strike occur it would change the world supply-demand balance in the second half of the year.

A number of copper projects that will have an important bearing on future longer-term supply made progress during the year. In March, Texasgulf Inc. signed agreements with the Republic of Panama for the evaluation and future development of the Cerro Colorado copper deposit in western Panama. The first phase of the project, if it is shown to be economically feasible, would include a mine, concentrator, smelter and refinery to produce 135 000 tonnes of copper metal each year. In a later phase, a phosphate fertilizer complex is contemplated. By April, Canadian miners were driving a 762-metre tunnel into the deposit to allow adequate sampling and metallurgical testing of the orebody. If the participants decide to develop the project, Texasgulf will take a 20 per cent equity participation and will construct the facilities and manage the operation for 15 years after start-up. The other partner, the government of Panama, will retain 80 per cent ownership and has an option to purchase Texasgulf's interest after 20 years of operation.

The shelving of the Tenke-Fungurume copper development project in the Republic of Zaire early in 1976 was a major shock to observers of the world copper market. The war in Angola had the effect of interrupting shipments of materials and equipment to Tenke-Fungurume. This factor, together with political uncertainties, escalating costs, uncertain prospects for transportation and low copper prices, caused the project to be postponed in mid-construction after the expenditure of $200 million. This decision will postpone development for an indeterminate period and have an impact on the medium-term world copper supply situation. The planned annual capacity of the project was 130 000 tonnes of copper cathode and 6 000 tonnes of cobalt. Production start-up was planned for 1978. The project is owned and financed by Japanese, British, United States and French interests, and the government of Zaire. Resumption of the project will depend upon copper prices and more stable financial conditions.

Consumption

World consumption of refined copper increased by 14.6 per cent in 1976 to 8 549 000 tonnes. The biggest increases were in Japan, the United States and West Germany where consumption increases relative to 1975 were 27.8, 29.2 and 16.9 per cent, respectively.

This increase, large as it was, proved insufficient to absorb the total increase in production, resulting in a further build-up of refined stocks during the year. Much of the increase can be accounted for in inventory shifts in the direction of the consumer. Consumer inventories had been reduced to exceptionally low levels during the 1974-1975 recession.

National stockpiles of copper

Three market-economy countries owned national stockpiles in 1976. These countries were the United States, Japan and France.

The United States strategic stockpile at the end of 1976 contained 18 000 tonnes of refined copper. A new set of goals for this stockpile was announced in October 1976. If approved by Congress, the new goal for copper would be 1.2 million tonnes, the estimated requirement for civilian and military needs for the first three years of an emergency. Purchasing could begin in late 1977 or in 1978.

The Japanese stockpiling program has an objective of 60 000 tonnes of copper and a budget of $100 million. The first purchase of 13 000 tonnes was made by the Metallic Mineral Stockpile Association of Japan on July 31, 1976. Further purchases were made during the second half of the year. At the end of 1976 the total holdings of the stockpile amounted to 50 000 tonnes.

Discussions were held at the intergovernmental level in 1976 to find an agreed method of stabilizing world copper prices. Creation of an international buffer stock scheme was proposed and received wide support from the developing countries. Estimates of the size of an effective buffer stock varied from 800 000 tonnes to 2.5 million tonnes. It was also suggested that such a stock could be composed of coordinated national stocks. The high cost, problems associated with implementing the complementary production and export controls, fears of stimulating long-term over-production and reluctance to interfere with functioning of the free market made most consuming countries, and a number of producing countries, reluctant to participate in such a scheme.

Stocks

The highly visible London Metal Exchange (LME) and New York Commodity Exchange (Comex) stocks of refined copper rose from 504 000 tonnes and 91 000 tonnes at the beginning of 1976 to 603 000 tonnes and 182 000 tonnes, respectively, at year-end.

World stocks of refined copper declined during the first six months of 1976. In the second half of the year stocks increased, resulting in a net increase for the year as a whole. According to the American Bureau of Metal Statistics, stocks for reporting countries at refineries and commodity exchanges were 1 357 000 tonnes at the end of 1975. These stocks decreased to 1 231 000 at the end of June and climbed to 1 442 000 at the end of December 1976.

Table 8. Canada, consumption of primary copper in manufacture of semifabricated products, 1975-76

	1975	1976^{p}
	(tonnes)	
Copper mill products — sheet, strip, bars, rolls, pipe, tubes, etc.	37 765	
Brass mill products — plate, sheet, strip, rods, bars, rolls, pipe, tubes, etc.	7 396	
Wire and rod mill products	127 445	
Miscellaneous	1 437	
Total	174 043	

Source: Statistics Canada.
^{p}Preliminary.

Other holders of refined copper stocks included the national stockpiles of France, Japan and the United States, copper consumers and metal merchants. These additional stocks are estimated to have been in excess of 500 000 tonnes at year-end, bringing total world stocks above 1.9 million tonnes. This is more than double the normal level of stocks and is a measure of the extremely depressed level of consumption in the 1974-76 period. The growth of these stocks was a severe depressant upon prices during that period with widespread ramifications for the copper producers and for the copper-producing countries.

International developments

As a result of initiatives begun late in 1975, international discussions between copper consuming and producing nations began in March 1976. These discussions were held at the intergovernmental level, under the auspices of the United Nations Conference on Trade and Development (UNCTAD).

The March meeting revealed a strong consensus among participants that a need existed for a permanent intergovernmental consultative body on copper. The relationship between such a body and UNCTAD was not defined, although a substantial number of countries favoured its independence, perhaps along the lines of the International Lead and Zinc Study Group (ILZSG). It was agreed that a further meeting would be convened no later than December 1976 to consider the report of a working sub-group on the terms of reference of the permanent body and on collected studies and statistics on copper.

Shortly after the March meeting, the fourth session of UNCTAD was held at Nairobi. This session, commonly referred to as UNCTAD IV, adopted resolution 93 (IV) in which the "Integrated Program for Commodities" was accepted. Through the integrated program it was intended that the export earnings of the developing countries would be improved, sustained, and stabilized by measures affecting international trade

Table 9. World mine production of copper, 1975-76

	1975	1976
	(000 tonnes)	
United States	1 280.0	1 461.8
U.S.S.R.	1 100.0	1 200.0
Chile	828.3	1 005.2
Canada	733.8	747.1
Zambia	676.9	708.9
Zaire	494.8	442.7
Poland	230.0	310.0
Philippine Republic	225.8	225.0
Peru	173.8	218.5
Australia	218.9	206.4
Republic of South Africa	178.9	197.8
Papua New Guinea	172.5	176.5
Yugoslavia	114.9	120.0
Japan	84.6	81.3
Mexico	78.2	80.0
Indonesia	63.5	68.4
Other communist countries	288.8	295.5
Other non-communist countries	371.2	409.0
Total	7 314.9	7 954.1

Sources: *World Metal Statistics*, April 1977, and Statistics Canada.

in each of 18 commodities financed by a "Common Fund". A number of possible measures was agreed upon, to be chosen as appropriate for each commodity, through a series of preparatory meetings followed by commodity negotiating conferences.

UNCTAD IV altered the events surrounding copper, which was prominent among the list of 18 commodities encompassed by the Integrated Program. The dialogue which began at the March meeting was then incorporated into the Integrated Program, and the second meeting, held late in September in Geneva, was designated as a Preparatory Meeting on Copper.

Unlike the March consultation, the September meeting revealed two divergent views of the best way to handle the problems of the world copper market. Some countries continued to advocate the creation of a permanent body on copper, others, including most developing countries, proposed an immediate international commodity agreement on copper with a buffer stock to be financed by the Common Fund, and possibly with production and export controls. It was agreed at the September meeting to create an Intergovernmental Expert Group on Copper (IEGC).

The terms of reference of the IEGC were: to examine appropriate measures, determine financial requirements, examine the copper market and initiate the collection and analysis of statistical data, consider interim measures and make recommendations to the subsequent Preparatory Meeting on Copper, to be held early in 1977.

The IEGC held its first meeting in November. The main result was agreement upon a list of studies to be carried out. Canada was one of the countries in the "nucleus", the group of countries which undertook to carry out this work. The studies were to be completed and distributed before the second meeting, scheduled for February 1977. Canada carried out six studies on the subjects of the structure, of trade, capital cost requirements, trends in prices, ore reserves, joint production of metals, and a permanent body on copper. The third IEGC meeting was scheduled for March, and the reconvened plenary for May, 1977.

Intergovernmental Council of Copper Exporting Countries (CIPEC)

A ministerial meeting of CIPEC was held in June in Paris, France. Mauritania applied for associate membership and was admitted, bringing the number of countries in CIPEC to eight. The prime purpose of the meeting was to decide upon a course of action when the agreed production and export cuts expired at the end of June 1977. Chile reaffirmed its intention to resume full production after June 30. Other member countries terminated production and export cuts following the meeting. CIPEC made no new initiatives during 1976 to stabilize or raise copper prices. Instead, the organization placed total reliance upon the UNCTAD copper meetings in which CIPEC and its member countries played an active role. At a further ministerial meeting held in Santiago in December CIPEC was reported to have examined and rejected the possibility of instituting a floor price for copper. The CIPEC quarterly review was upgraded considerably during the year to include a forum for contributions on the copper market by authors from widely diverse backgrounds and to provide a regular commentary on current news items from member countries.

Table 10. World production of refined copper, 1975-76

	1975	1976
	(000 tonnes)	
United States	1 609.4	1 722.0
U.S.S.R.	1 420.0	1 440.0
Japan	818.9	864.4
Zambia	629.1	694.9
Chile	535.2	632.0
Canada	529.2	510.5
Belgium	331.6	457.7
West Germany	422.2	446.6
Poland	248.6	270.0
Australia	193.3	187.6
Spain	130.2	143.7
Peru	53.0	143.6
United Kingdom	151.5	137.2
Yugoslavia	137.9	130.0
Republic of South Africa	86.4	85.0
Mexico	69.8	83.3
Zaire	225.9	66.0
Sweden	56.2	59.5
Other communist countries	433.5	459.5
Other non-communist countries	279.6	301.9
Total	8 361.5	8 835.4

Sources: *World Metal Statistics*, April 1977 and Statistics Canada.

Copper industry market outlook

The economic recovery in the world's industrialized countries took place at a slower-than-expected pace in 1976. As a result, actual copper consumption was disappointing. Demand, however, increased by 14.6 per cent relative to that experienced in 1975 due in part to inventory rebuilding. Consumption and demand for copper are expected to increase by a further 5 per cent in 1977.

Supply capacity is expected to continue to increase with the addition of 250 000 tonnes of new mine capacity in 1977 and a further 950 000 tonnes by 1980.

The key to the copper market outlook in the period 1977-80 lies in the level of demand experienced. Unless demand growth exceeds 5 per cent per year during that period, over-capacity, over-supply and

Table 11. World consumption of refined copper, 1975-76

	1975	1976
	(000 tonnes)	
United States	1 396.3	1 803.7
U.S.S.R.	1 200.0	1 250.0
Japan	821.8	1 050.3
West Germany	634.6	742.0
United Kingdom	450.5	457.6
France	364.5	378.0
Italy	290.0	335.2
Belgium	177.4	225.1
Canada	185.2	206.3
Brazil	155.2	179.3
Poland	160.0	160.0
Yugoslavia	106.1	140.0
Spain	119.4	132.9
East Germany	112.0	120.0
Australia	102.8	115.4
Sweden	94.4	89.4
Other communist countries	532.7	561.5
Other non-communist countries	555.6	602.3
Total	7 458.5	8 549.0

Source: *World Metal Statistics*, April 1977.

Table 12. World copper production and consumption, 1976

	Mine Production	Refined Production	Refined Consumption
	(000 tonnes)		
United States	1 461.8	1 722.0	1 803.7
U.S.S.R.	1 200.0	1 440.0	1 250.0
Japan	81.3	864.4	1 050.3
CIPEC	2 835.6	1 724.1	173.8
Europe	297.9	1 511.8	2 688.4
Canada	747.1	510.5	206.3
Other communist countries	605.5	729.5	841.5
Other non-communist countries	724.9	333.1	535.0
Total	7 954.1	8 835.4	8 549.0

Sources: *World Metal Statistics*, April 1977 and Statistics Canada.

depressed prices are probably in store. Supply disruptions in Southern Africa and a copper industry strike in the United States in this period are, however, distinct possibilities and could significantly alter the supply-demand position.

The level of world stocks of refined copper, which were in a declining trend during the first half of 1976, rose again in the second half of the year. Should supply continue to outstrip demand in 1977 production cuts may again become necessary.

The recent period of low prices has greatly increased the impetus for an international commodity agreement on copper. If there is no breakdown or delay in the series of intergovernmental discussions begun in March 1976 it is possible that a negotiating conference, leading to such an agreement, may be called some time in 1978.

Most world copper producers are in a weakened financial position as a result of low copper prices in 1975 and 1976, and not well placed to undertake capacity expansions. Developing countries with access to capital through international development agencies, and having large undeveloped resources, appear better able to undertake construction of new capacity. It appears likely that the proportion of the world copper market supplied from these countries will increase in the future.

Prices

A most unusual feature of the course of copper prices in 1976 was that producer prices actually led the free market price during part of the upward moves which took place during the year. This is the reverse of the pattern established in previous price cycles during the last 15 years and is a reflection of the urgent need of producers to realize higher profit levels than were experienced during 1975.

Copper prices opened in 1976 at the depressed levels which had prevailed during most of 1975. The LME cash price for wirebars at the beginning of January was 54 U.S. cents a pound. The price of copper wirebars was 63.625 U.S. cents a pound in the United States and 63.375 cents a pound in Canada. In March an upward move began which peaked in July with cash prices for LME wirebars above 76 U.S. cents a pound. Producer prices also reached their highest level for the year in July, and remained unchanged until October at 74.625 U.S. cents a pound for wirebars and 74.00 U.S. cents a pound for cathode in the United States, and 72.375 and 71.75 Canadian cents a pound for wirebars and cathode in Canada. By October LME prices had fallen back to the 55-60 U.S.-cents-a-pound range, seriously undermining North American producer prices. Producer prices broke down by 4 cents a pound in October and by a further 5 cents a pound at the end of November. At year-end a firming trend in prices appeared to be developing again and LME cash price for wirebars was 61.5 U.S. cents a pound. Producer prices in the United States were 65.625 U.S. cents a pound for wirebars and 65.00 U.S. cents a pound for cathode. Corresponding Canadian prices were 67.125 and 66.5 Canadian cents a pound, respectively.

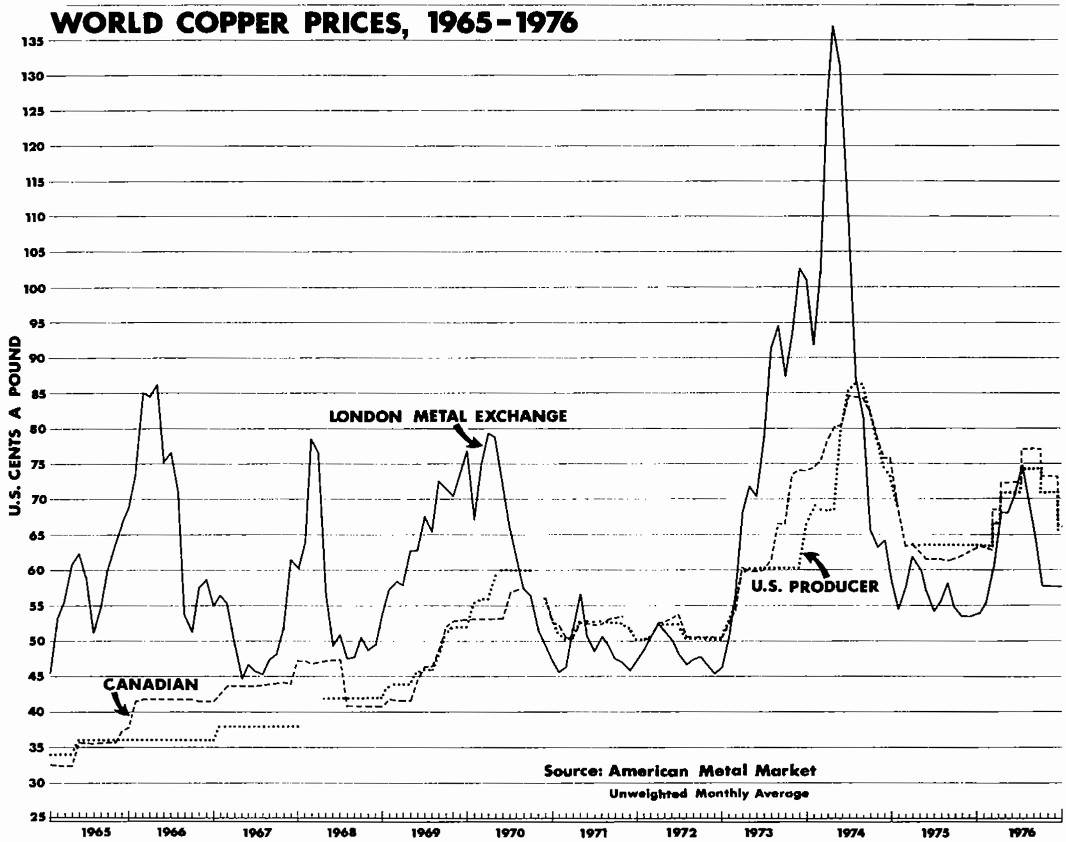


Table 13. Canadian and world refined copper production, refined copper consumption and stocks, 1975 and 1976; forecast for 1977 and 1980.

	1975	1976	1977	1980
		(000 tonnes)		
Mine production				
Canada	734	747p	800	870
Non-communist countries	5 731	6 125	6 431	7 000
Total World	7 350	7 931	8 328	9 100
Smelter production				
Canada	496	489	500	600
Non-communist countries	5 858	6 293	6 608	7 100
Total World	7 489	8 072	8 476	9 100
Refinery production				
Canada	529	510p	520	600
Non-communist countries	6 259	6 666	6 999	7 500
Total World	8 362	8 835	9 277	9 900

Table 13. (concl'd)

	1975	1976	1977	1980
		(000 tonnes)		
Refined copper consumption				
Canada	196	215	226	248
Non-communist countries	5 465	6 467	6 790	7 463
Total World	7 496	8 558	8 986	9 877
Estimated non-communist countries' mine capacity	6 700	6 900	7 150	8 200
% utilization of mine capacity	86	89	90	85
Total World refined stocks	1 800	1 900	1 900	2 500

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[p] Preliminary.

Tariffs

Canada

Item No.		GSP[1]	British Preferential	GATT	General
32900-1	Copper in ores and concentrates	free	free	free	free
33503-1	Copper oxides	free	free	15%	25%
34800-1	Copper in pigs, blocks or ingots, cathodes, plates, copper matte and blister and copper scrap, per lb	free	free	free	1½¢
34820-1	Copper in bars or rods, for manufacture of trolley, telegraph, telephone wires, electric wires and cables	free	free	5%	10%
34835-1	Electrolytic copper powder (expires Feb. 28, 1978)	free	free	free	10%
34845-1	Electrolytic copper wire bars, per lb (expires Feb. 28, 1978)	free	free	free	1½¢
35800-1	Anodes of copper	free	free	free	10%

United States

USTS No.		GSP	GATT
602.30	Copper ores and concentrates, on Cu content	free	0.8 cents a pound
612.06	Unwrought copper, on Cu content	free	0.8 cents a pound
612.10	Copper waste and scrap, on 99.6% of Cu content	free	0.8 cents a pound

Tariffs (concl'd)

Japan

BTN No.		GSP	GATT
26.01	Copper ores and concentrates	free	free
74.01	1. Matte, cement copper & native copper	free	free
	2. Unwrought copper, other than matte, cement and native copper		
	(i) containing not more than 99.8% by weight of copper and used for smelting and refining	free	8.5%
	(ii) other — blister	free	8.5%
	— other categories	free	24 Y per kg
	3. Waste and scrap	free	2.5%

EEC

BTN No.		GSP	GATT
26.01	Copper ores and concentrates	free	free
74.01	Copper matte; unwrought copper; copper waste and scrap	free	free

[1]GSP Generalized System of Preferences extended to all, or most, developing countries; some GSP rates are subject to quotas or withdrawal.

Fluorspar

G.H.K. PEARSE

Fluorspar, or fluorite in mineralogical nomenclature, is calcium fluoride (CaF_2), an industrial mineral with a broad spectrum of uses. The most important of these are: for the manufacture of hydrofluoric acid and other fluorine chemicals; as a fluxing agent in various metallurgical processes, the most important being steel manufacture; for the manufacture of artificial cryolite, an essential cell ingredient in the electrolytic reduction of alumina to aluminum; in the refining of uranium ores, and in the glass and ceramic industries.

In the past decade, world fluorspar consumption grew rapidly because of increasing demands in the steel, aluminum and chemical industries. Due to a combination of technical, economic and environmental developments, consumption has been stagnant during the first half of the present decade. In 1976 world production was an estimated 4.4 million tonnes*. Greater use of the basic oxygen process in steelmaking, which requires about three times as much fluorspar as a slag thinner than the more traditional basic open-hearth process, will increase the demand for fluorspar in this sector in spite of the partial use of substitutes. However, slack demand in the steel industry over the last two years has arrested growth in metallurgical-grade fluorspar consumption. Recent concern about concentrations of fluorocarbons in the upper atmosphere has led to plans by the United States Government to phase out non-essential uses of these chemicals. Aerosol spray products are alleged to be the main offenders.

Production in Canada

Fluorspar is the principal source of the element fluorine. It occurs in many geological environments from low-temperature fracture fillings to high-temperature emplacements and, as a result, it is not restricted to any particular geological province in Canada. In fact, fluorspar is known to occur in all physiographic provinces with the exception of the interior plains. However, all fluorspar produced in Canada is currently mined from the Burin Peninsula in Newfoundland by one company.

Newfoundland Fluorspar Works of Aluminum Company of Canada Limited (Alcan), produces fluorspar from three mines: Director, Tarefare, and Blue Beach. The three mines are located near the village of St. Lawrence in Newfoundland. The Director mine has been in operation for 34 years. The Tarefare mine commenced production at about 25 000 tonnes a year of fluorspar concentrate in 1968. Production from the Blue Beach mine began in 1972 and the mill capacity has been increased to 1 200 tonnes of ore a day. Concentrates from these operations are shipped to Alcan's aluminum smelter at Arvida, Quebec, where they are upgraded by flotation and converted to aluminum fluoride for the reduction of alumina to aluminum. Small tonnages have been sold from time to time to Newfoundland Steel Company Limited for steel slagging. In 1976 shipments from Newfoundland were about half normal at 64 000 tonnes because of a strike which began in June 1975 and did not end until March 1976. Developments on extensive new reserves about a mile northwest of St. Lawrence were halted by the strike. The fluorspar veins on Burin Peninsula are genetically related to two large stocks of alaskite. Most of this favourable area is obscured by shallow overburden, but innumerable showings and float blocks containing fluorspar are known.

Allied Chemical Canada, Ltd., imports acid-grade fluorspar for the production of hydrofluoric acid at Valleyfield, Quebec and Amherstburg, Ontario. Some of the acid is utilized in the manufacture of various fluorine chemicals. Allied Chemical operates mines in Mexico and the United States to ensure an uninterrupted supply of fluorspar.

Huntingdon Fluorspar Mines Limited, with a plant near North Brook, Ontario, imports metallurgical-grade fluorspar to make five-pound briquettes for foundry use.

International Mogul Mines Limited's barite-fluorite deposits east of Lake Ainslie, Cape Breton Island, Nova

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, fluorspar production, trade and consumption

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Newfoundland	—	—	—	2 246 000
Imports				
Mexico	85 306	6 813 000	62 192	4 917 000
Spain	42 258	3 649 000	52 941	4 683 000
United States	18 692	1 637 000	11 009	884 000
Morocco	—	—	9 081	727 000
United Kingdom	2 566	259 000	2 087	184 000
Italy	8 400	674 000	—	—
Total	157 222	13 032 000	137 310	11 395 000
Consumption[1] (available data)	1974[r]		1975	
Metallurgical flux[2]	33 303	..	26 154	..
Chemicals	12 875	..	12 226	..
Petroleum refining	5 122	..	1 885	..
Other[3]	185 708	..	161 861	..
Total	237 008	..	202 126	..

Source: Statistics Canada.
[1]As reported by consumers; breakdown by Mineral Development Sector. [2]Consumption as flux in the production of steel and magnesium, and use in foundries. [3]Includes consumption in the production of aluminum and other miscellaneous uses.
[p]Preliminary; [r]Revised; .. Not available; — Nil.

Scotia have indicated ore reserves of 2.7 million tonnes grading 28 per cent barite and 19 per cent fluorite. Pilot plant testing, with the objective of producing an acid-grade concentrate at an acceptable rate of recovery, has yet to prove successful. From 1940 to 1949, approximately 1 300 tonnes of fluorspar, along with some barite, were recovered from this deposit.

Prior to the First World War, small tonnages of fluorspar were mined from vein-type deposits in the Madoc district of Ontario. As a strategic material of great importance, it showed a marked increase in production during the war. After the war, production decreased substantially, but was stimulated once again during the Second World War by government assistance for exploratory drilling programs and by loans on capital equipment. From 1943 to 1947 some 23 000 tonnes were mined. Fluorspar was mined continuously in the Madoc area up to 1961, when severe underground flooding, lack of export markets, and increased mining costs made the operation uneconomic. Altogether, some 140 000 tonnes of fluorspar were mined in the Madoc area, production being derived from 24 separate properties. Most significant producing properties were along a prominent linear vein structure, the southern extension of which could still contain economically attractive reserves.

The Rock Candy mine, near Grand Forks, British Columbia, was mined intermittently from 1918 to 1942 and is controlled by Cominco Ltd. Substantial reserves probably remain.

Fluorine is being recovered as fluosilicic acid from the processing of phosphate rock by Erco Industries Limited (formerly Electric Reduction Company of Canada, Ltd.), at Port Maitland, Ontario, and by Cominco Ltd., at Trail, British Columbia.

Other fluorspar occurrences of interest include the Liard River, British Columbia deposits explored a few years ago by Jorex Limited and Conwest Exploration Company Limited; Eaglet Mines Limited's widespread low-grade mineralization near Quesnel, British Columbia and Consolidated Rexspar Minerals & Chemicals Limited's large uranium-bearing, medium-grade fluorspar deposit adjacent to the Canadian National Railway line at Birch Island, about 95 kilometres north of Kamloops.

Uses, markets and trade

The major uses of fluorspar are: as a fluxing material in metallurgical and related industries, in the chemical industry for the manufacture of hydrofluoric acid and other fluorine compounds, in the glass and ceramic industries, in the refining of uranium ores and concentrates, and in the manufacture of artificial cryolite utilized in aluminum refining. Minor quantities of clear, transparent, colourless fluorite are used in optical equipment.

Fluorspar is marketed in three grades according to end-use, although, in time of shortage of metallurgical grade, high-grade material is substituted for this normally lower-grade material. These three grades are: acid grade, containing a minimum of 97 per cent CaF_2; metallurgical grade, containing 60-80 per cent CaF_2; and ceramic grade, containing 88-97 per cent CaF_2.

Acid grade. Roughly 50 per cent of the world's fluorspar requirement is for acid grade and is used in the manufacture of hydrofluoric acid. Most of this material is beneficiated by flotation to achieve the high CaF_2 content required. In general, two to three tonnes of ore must be mined to produce one tonne of acid-grade fluorspar concentrate, and the production of one tonne of hydrofluoric acid requires two tonnes of acid-grade concentrate and almost three tonnes of sulphuric acid. Hydrofluoric acid, produced according to the reaction

$$CaF_2 + H_2SO_4 \rightarrow CaSO_4 + 2\,HF$$

has a variety of uses, but by far the most important is in the aluminum and fluorocarbon industries which account for some 80 per cent.

About one-third of all hydrofluoric acid produced is used by the aluminum industry. Hydrofluoric acid is reacted with a sodium salt and aluminum fluoride to produce artificial cryolite, an essential cell ingredient for fluxing in the electrolytic reduction of alumina to aluminum. In general, about 23 kilograms of cryolite and 20 kilograms of aluminum fluoride are required for the production of one tonne of primary aluminum. This is equivalent to 65 to 70 kilograms of acid-grade fluorspar concentrate. Allowing for increased cell efficiencies and fluorite recoveries from potlines, the above figure should be reduced to 60 kilograms per tonne of primary aluminum. Because fluorite is an essential raw material, many primary aluminum producers operate, or participate in the operation of, fluorspar mines to ensure uninterrupted and adequate supplies.

Over 40 per cent of hydrofluoric acid is consumed in the manufacture of fluorocarbons. Fluorocarbons, which are used in the manufacture of solvents, resins, plastics, films, refrigerants and aerosol propellants, are produced by reacting hydrofluoric acid with carbon tetrachloride, or with chloroform. Fluorocarbons are currently under study as potentially harmful atmospheric pollutants. It is alleged that these substances react with the ozone layer in the upper atmosphere which filters out much of the sun's ultraviolet energy. The resulting increase in ultraviolet radiation could increase the incidence of skin cancer.

Fluorspar is used in uranium refining. Uranium dioxide is reacted with anhydrous hydrofluoric acid to form a green salt (UF_4), which is then reacted with elemental fluorine in the form of fluorine gas to form

Table 2. Canada, fluorspar production, trade and consumption, 1965, 1970, 1974-76

	Production[1]	Exports	Imports	Consumption
	(tonnes)			
1965	102 000	..	63 365	151 987
1970	124 103	..	85 894	193 184
1974	136 000[e]	..	142 246	237 008[r]
1975	64 000[e]	..	157 222	202 126
1976[p]	64 000[e]	..	137 310	..

Sources: Statistics Canada, company data, U.S. Bureau of Mines.
[1]Shipments reported in annual reports of Aluminum Co. of Canada Ltd. for 1965 and 1970. Shipments 1974-76 are estimates based on the U.S. Bureau of Mines, Commodity Data Summaries, 1977.
[p]Preliminary; [e]Estimated; [r]Revised; .. Not available.

UF_6, the feedstock for plants requiring enriched uranium. For each tonne of uranium processed into uranium hexafluoride, one and two-third tonnes of fluorspar are required. This presently-minor use is expected to develop rapidly as nuclear energy becomes increasingly more important.

Metallurgical grade. About half of the world's fluorspar output is consumed as a metallurgical fluxing agent, primarily in the manufacture of steel. Metallurgical-grade fluorspar is used in the steel industry to remove impurities during melting and also to improve separation of metal and slag in the furnace by increasing the fluidity of the slag. Consumption of fluorspar in the steel industry has, in recent years, increased substantially because of changing technology. Many steel-makers have shifted from the basic open-hearth process to the basic oxygen process. The latter consumes from 5 to 8 kilograms of metallurgical-grade fluorspar for each tonne of steel produced, compared with 1.5 to 2.5 kilograms in the open-hearth process. The electric furnace process consumes from 4 to 5 kilograms of metallurgical-grade material for each tonne of steel produced. The basic oxygen process substantially reduces production costs, doubles capacity per unit dollar of capital cost and reaches heat much faster than the open-hearth process. Within the next decade, older basic open-hearth furnaces should be replaced by more efficient, new basic oxygen or electric furnaces. Faced with higher prices and uncertain supply conditions, the steel industry will attempt to find methods of reducing consumption of fluorspar. In addition, some major consumers have become involved in exploration for fluorspar reserves. No satisfactory total substitute for fluorspar as a fluxing agent in steelmaking has been found, although research in this area is considerable and indications are that the growth of metallurgical-grades reserves is not keeping pace with requirements. Consequently, steelmakers may have to switch more and more to higher-grade, higher-cost material, produced as flotation concentrates and converted into pellet or briquette form. World consumption in the steel industry is currently about 3 million tonnes a year. Metallurgical-grade fluorspar is also used as a flux in foundries and in the reduction of dolomite to magnesium.

Ceramic grade. Ceramic-grade fluorspar is used as an opacifier in enamels and opal glass. It is also used to a limited extent in the manufacture of clear glass as an active flux, as a contributor to the gloss and as a decolourizer. Much of this grade of fluorspar concentrates can be used for the manufacture of hydrofluoric acid, or as pellets and briquettes for steelmaking. This latter requirement has been provided for in this way during shortages of metallurgical-grade fluorspar.

Canadian consumption and trade

About 80 per cent of fluorspar consumed in Canada, and virtually all domestic production, is used in the manufacture of aluminum fluoride for the electrolytic reduction of alumina to aluminum.

In 1976 fluorspar imports were 137 310 tonnes, a decrease of 12.7 per cent from the previous year. Imports tend to vary widely from year to year in an inverse relationship to variations in production. Mexico provided 45 per cent of total imports, Spain provided 39 per cent and the remainder came from the United States, Morocco and the United Kingdom.

Prior to 1957, much of Canadian production was exported to the United States and Europe. In 1958 exports declined abruptly because of the development of alternative low-cost deposits in Mexico by large consumers in the United States.

World review

Rapid growth in fluorspar consumption by the steel, chemical and aluminum industries, coupled with a stagnant ore-reserve situation during the 1960s, raised fears of a shortage towards the end of the decade. Under the impetus of tightening supply and rising prices, intensive exploration efforts in various parts of the world were successful in substantially augmenting reserves. Expanded and new facilities were brought on stream to meet the expected strong demand. However, coincident with the surge in production came a slackening in demand due to an economic slowdown in the major consuming nations, notably the United States and Japan. During the latter part of 1971 and the first half of 1972 an over-supply situation, especially of acid-grade material, developed in many areas. Strong growth in consuming sectors in 1974 was met by withdrawals from large inventories, notably in Europe where output was deliberately cut back. Entry into recession precluded stimulation of production during 1975 and 1976. World production at 4.4 million tonnes in 1976 is little changed from that of the previous six years.

Mexico continued to rank as the world's largest supplier, producing 1 million tonnes, or 22.5 per cent of total output, in 1976. Fluorspar mining began in Mexico prior to the First World War. However, the industry received its greatest stimulus during the Second World War, when the United States government, cut off from European sources, encouraged exploration and development in Mexico. Most production is mined in the State of San Luis Potosi in the Zaragoza area where two major producing mines are located within a mile of each other. The Las Cuevas mine, which is the largest, accounts for some 40 per cent of total Mexican metallurgical-grade output. This underground operation is an affiliate of Noranda Mines Limited. The rapid growth of fluorspar production in Mexico from 430 000 tonnes in 1963 has paralleled consumption increases in the United States, which relies upon Mexico for most of its import requirements. Similarly, stagnation of production over the last few years reflects the United States' demand.

Table 3. World fluorspar production, 1974-76

	1974	1975	1976[e]
		(tonnes)	
Mexico	1 112 000	1 089 000	998 000
U.S.S.R.	450 000	475 000	500 000
Spain	376 000	363 000	345 000
People's Republic of China	270 000	320 000	330 000
Mongolia	240 000	272 000	290 000
France	272 000	245 000	245 000
Thailand	390 000	218 000	236 000
Republic of South Africa	208 000	202 000	227 000
United Kingdom	235 000	231 000	218 000
Italy	245 000	231 000	218 000
United States	182 000	127 000	163 000
Canada	136 000	64 000	64 000
Other countries	550 000	550 000	600 000
Total	4 666 000	4 387 000	4 436 000

Source: U.S. Bureau of Mines, Commodity Data Summaries, 1977.
[e] Estimated.

Quimica Fluor S.A.'s hydrofluoric acid plant at Matamoros started up in 1975. It is one of four originally proposed in 1971.

The Mexican Fluorspar Institute, a producer organization, was formed in 1974. This body, backed by the government, formulates policy on sales and prices.

The United States is the world's largest consumer and is heavily reliant on imports to meet demand. In 1976 United States production increased by 35 per cent, to 150 668 tonnes, as the industry recovered from strikes in 1975. Imports for the year totalled 812 158 tonnes, 74 per cent from Mexico. Most output in the United States comes from the Illinois-Kentucky district and is produced by two companies, Ozark-Mahoning Company (majority interest purchased by Pennwalt Corporation during 1975) and Allied Chemical Corporation which, through acquisition, took over the former Minerva Oil Company holdings. The mine and mill of Cerro Corporation near Salem, Kentucky, was acquired (95 per cent) by Frontier Resources Inc. of Denver, Colorado, in 1976. A new mine near Hampden, Kentucky is also being evaluated by this company. A new company, Kenspar, will begin mining from several properties, and the ore will be milled at Mexico, Kentucky. Other states producing fluorspar intermittently are: Montana, Colorado, Idaho, Arizona, New Mexico and Utah. Little news of developments at Lost River Mining Corporation Limited's reportedly-extensive deposits near Teller, Alaska was forthcoming during the year. Drilling by United States Borax & Chemical Corporation on its new fluorspar-barite deposit in the Sweetwater district, 65 kilometres southeast of Knoxville, Tennessee, has thus far delineated over 50 million tonnes of 15 to 35 per cent CaF_2 amenable to open-pit mining. Production from this property is unlikely to be commissioned before 1980.

In 1976 Spain produced an estimated 345 000 tonnes. Much of the Spanish production is exported, mostly to the United States and West Germany. Estimated French production was 245 000 tonnes. Italy, also a major producer, shipped an estimated 220 000 tonnes in 1976. Production in Britain was also about 220 000 tonnes in 1976.

The U.S.S.R. is the world's second-largest producer of fluorspar, with an output of about 500 000 tonnes in 1976. Domestic supply has fallen short of requirements for some years, and imports in 1976 exceed 300 000 tonnes. The People's Republic of China, North Korea and Mongolia, a rapidly growing producer, together produce approximately 500 000 tonnes a year.

Thailand's output remained substantially below the 1971 figure of 420 550 tonnes. As a result of cutbacks in orders, principally from Japan, production in 1976 was an estimated 236 000 tonnes. Reserves are reportedly 11 million tonnes of 60 per cent CaF_2 and large deposits indicated in the upper reaches of the River Kwai have received attention. Limiting factors on production and market development include primitive mining and beneficiation techniques, and costly and difficult transportation from producing areas to points of export. Loading facilities at Bangkok also present a bottleneck to efficient ocean transport. The Thai government has taken an active interest in the industry and is moving to eliminate these drawbacks. A United Nations study and report on these problems was completed during 1975.

The Republic of South Africa's output, which more than doubled between 1968 and 1971 to 235 000 tonnes, was an estimated 227 000 tonnes in 1976. This country has about 25 per cent of the world's measured CaF_2 reserves and its production will likely represent an increasing share of world output over the long term.

Namibia (formerly South-West Africa), Kenya, Tunisia and Morocco are all significant producers.

Until recently, South America produced limited quantities of hand-sorted, metallurgical-grade fluorspar. Exploration and development is moving along rapidly in both Brazil and Argentina, and output from this continent has risen to about 120 000 tonnes.

Prices

United States fluorspar prices, quoted in "Engineering and Mining Journal" of December 1976

(net short ton fob Illinois and Kentucky, CaF_2 content, bulk)

	($)
Ceramic, calcite and silica variable, CaF_2	
88-90%	90-100
95-96%	95-106
97%	100-115
In 100-lb paper bags, extra	9
Metallurgical, pellets, 70% effective CaF_2	83-91
Acid, dry basis, 97% CaF_2	
Carloads	95-115
Less than carload	..
Bags, extra	9
Pellets, 88% effective	111
Wet filter cake, 8-10% moisture, sold dry content — subtract approx.	3.00
Dry acid concentrates fob Wilmington, 97% CaF_2 st	..
European and South African wet filter cake, 8-10% moisture, sold dry content, duty pd., st, cif East Coast, Great Lakes and Gulf ports, term contracts	102.50-105.00
Mexican	
Metallurgical 70% fob cars	
Mexican border, fob cars	62.92
Tampico, fob vessel	65.52
Acid, 97% + Eagle, Pass, bulk	79.38

.. Not available.

Outlook

The performance of the fluorspar industry necessarily parallels development in the steel, chemical and aluminum industries, which together account for 95 per cent of fluorspar consumption.

Conversion from the open-hearth process to the basic oxygen process for steelmaking, and vigorous growth in the chemical and aluminum industries during the 1960s accelerated fluorspar consumption. A hiatus in this growth during 1971 and much of 1972 obviated a tight-supply situation, and both consumer and producer stocks, particularly of acid grade, grew substantially. A boom in 1974 was arrested by year-end as the world economic climate deteriorated, and output remained static during 1975 and 1976.

World steel demand by the early 1980s is expected to exceed one billion tonnes, and continued growth in the BOF process for steelmaking will be the mainstay of growth in the fluorspar industry.

Consumption of fluorspar in the aluminum industry is expected to level off over the medium term as fluorine emissions from potlines are reduced and greater efficiency in recycling is achieved. Also, recovery of fluorine from phosphate rock processing has begun, and is currently substituting for fluorspar in the aluminum industry. This source of fluorine will grow in importance. The outcome of the controversy over the environmental effects of fluorocarbons is likely to weigh in favour of caution, and decline in this sector could result. These negative effects on the demand for fluorspar will undoubtedly be compensated for in the long-term by accelerated use in uranium refining and developments in the chemical industry.

Fluorine, the most electronegative of all elements, reacts with almost all organic and inorganic substances and in view of this property, only the surface of its potential as a chemical has been scratched.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29600-1	Fluorspar	free	free	free	free

United States

		($/lt)
522.21	Fluorspar, containing over 97% calcium fluoride	2.10
522.24	Fluorspar, containing not over 97% calcium fluoride	8.40

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. For United States, Tariff Schedules of the United States, Annotated (1976) T.C. Publication 749.

Gold

J.J. HOGAN

Gold production in Canada in 1976 was estimated at 52 444 000 grams (1 686 000 ounces*) valued at $207 796 000 compared with 51 433 114 grams (1 653 613 ounces) in 1975 valued at $270 830 389. The average yearly afternoon fixing prices of gold on the London Gold Market converted to equivalent Canadian dollars for the years 1976 and 1975 were $3.946 a gram ($122.72 an ounce) and $5.266 a gram ($163.78 an ounce) respectively. The value of gold production in 1976 declined by 23.3 per cent because of the sharp decline in the gold price. Volume of production increased by 1.9 per cent in 1976, the first increase in Canadian gold output since 1960 when 143 975.2 kilograms (4 628 911 ounces) were produced. Both lode gold and base-metal mines recorded increases. The largest gold production in Canada for any year was 1941 when 166 253.7 kilograms (5 345 179 ounces) were produced.

Canada has been one of the world's leading producers of gold and, since production was first officially recorded in 1858, has produced 6 306 306 kilograms (202.75 million ounces) to the end of 1976 valued at $7 368 million. Although most of the provinces and territories have contributed to the total output, the largest producers, in decreasing order of output, were Ontario, Quebec, British Columbia, Yukon Territory and the Northwest Territories.

In 1976 the lode gold mines in Canada accounted for 71.8 per cent of the country's gold output and produced 37 664 000 grams of gold compared with 37 529 456 grams in 1975. Production of gold from lode mines was up slightly because some of the mines were forced to mine better-grade ore as one factor in lowering the production cost of an ounce of gold in order to help offset the sharp drop in the gold price. At the end of 1976 there were 22 operating gold mines in Canada. One mine began operations in 1976, another opened in the first part of the year but was forced to close because of financial problems, and a third mine was closed because its ore reserves were exhausted. Gold derived from base-metal mining was 14 354 000 grams compared with 13 568 581 grams in 1975. A small amount of gold was recovered from placer deposits in the Yukon Territory and British Columbia. Ontario continued to be the major gold producing province in Canada and accounted for 43.5 per cent of the national total, followed by Quebec with 28.1 per cent, Northwest Territories, 11.2 per cent and British Columbia, 10.5 per cent.

Lower-grade and some medium-grade Canadian gold mines experienced serious financial problems in 1976 because of the sharp decline in the gold price. In July the price declined to about U.S. $120 an ounce from the price at the beginning of the year of U.S. $140.35, partly because of the unknown effect the gold sales by the International Monetary Fund would have on the gold price on the world market. The problem was aggravated by a further drop in the gold price to an average of U.S. $109.93 for the month of August. This low gold price threatened the life of several mines and the closures would have had an adverse effect on the economy of the communities in which they are located. At that time the mine operators approached the federal government for financial assistance to ensure the continued operation of the mines until the price of gold improved, or until it was clearly established that the price would remain at, or near, its low level. Representatives from the gold mining communities also approached the governments to provide assistance to the mines at a level sufficient to keep them operating and thus maintain the economy of the communities. In order to operate at a profit, or at a reduced loss, the mine operators took steps to improve their position by adopting such measures as mining higher-grade ore, curtailing development and reducing their labour forces.

An increase in the gold price in the latter part of the year, resulting from increased demand for gold, and indications that the market could absorb the extra gold from the International Monetary Fund sales, eased

*The term "ounce" refers to the troy ounce throughout unless otherwise stated. 1 troy ounce = 31.103 48 grams.

many of the problems faced by the Canadian mine operators. However, even with improved gold prices, two or three mines could close in 1977 because of operating cost factors or exhaustion of ore reserves. In all probability the mine operators will reappraise the cutbacks made on exploration and development work and reinstate some of these programs.

The Emergency Gold Mining Assistance Act (EGMA Act) expired on June 30, 1976. The terms of the Act were not applicable to today's gold industry and were not a vehicle through which troubled mines could be extended assistance in 1976. The Act came into force in 1948 to provide financial assistance to marginal gold mines which were facing increasing costs of producing an ounce of gold, while receiving a fixed price for gold produced. The EGMA subventions enabled the gold mines to extend their productive life, thereby allowing the dependent communities to adjust to diminishing economic support over a longer period of time. In some cases the economic impact of gold

Table 1. Canada, production of gold, 1975-76

	1975	1976p
	(grams)	
Newfoundland		
Base-metal mines	404 096	405 000
New Brunswick		
Base-metal mines	105 472	125 000
Nova Scotia		
Base-metal mines	93	–
Quebec		
Auriferous quartz mines		
Bourlamaque-Louvicourt	4 013 095	4 227 000
Malartic and Matagami	6 271 239	6 613 000
Total	10 284 334	10 840 000
Base-metal mines	3 871 108	3 903 000
Total Quebec	14 155 442	14 743 000
Ontario		
Auriferous quartz mines		
Larder Lake	4 985 421	4 779 000
Porcupine	8 283 260	8 473 000
Red Lake and Patricia	8 515 790	7 724 000
Total	21 784 471	20 976 000
Base-metal mine	1 703 258	1 854 000
Total Ontario	23 487 729	22 830 000
Manitoba-Saskatchewan		
Base-metal mines	1 951 339	2 022 000
Placer operations	–	–
Total Manitoba-Saskatchewan	1 951 339	2 022 000
Alberta		
Placer operations	7 651	–
British Columbia		
Auriferous quartz mines	–	–
Base-metal mines	4 820 914	5 466 000
Placer operations	41 742	40 000
Total British Columbia	4 862 656	5 506 000
Yukon		
Base-metal mines	712 301	579 000
Placer operations	285 685	386 000
Total Yukon	997 986	965 000
Northwest Territories		
Auriferous quartz mines	5 460 651	5 848 000
Base-metal mines	–	–
Total Northwest Territories	5 460 651	5 848 000
Canada		
Auriferous quartz mines	37 529 456	37 664 000
Base-metal mines	13 568 581	14 354 000
Placer operations	335 077	426 000
Total	51 433 114	52 444 000
Total value	$270 830 389	$207 796 000[1]
Average Value per oz[2]	$163.78	$123.11

Sources: 1975, Statistics Canada; 1976, Statistics Canada and company reports. Breakdown by type of operation by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Value not necessarily based on average gold price for 1976. [2]Average of London Gold Market afternoon fixings in Canadian funds.
pPreliminary; – Nil.

mine closures was offset by the development of a new economic base. The amount paid to gold mine operators during the life of the Act totalled $303 104 402 on a production of 1 922.6 tonnes* (61 813 545 ounces) of gold produced and sold in accordance with the requirements of the Act.

On July 30, 1975 Parliament gave Royal Assent to an Act to amend the existing Olympic (1976) Act, passed in 1973, and this amendment authorized the issue for circulation in Canada of gold $100 coins commemorating the Olympic Games of 1976 and bearing the date 1976. This new legislation also provided that each of the new Olympic gold coins will be legal tender.

The number of gold coins minted in 1976 was 650 000 uncirculated 14-carat gold coins and 350 000 22-carat proof coins. The specifications for the 14-carat gold coins are: gold, 58.3 per cent; copper, 31.3 per cent; silver, 4.0 per cent; zinc, 6.4 per cent; weight, 13.34 grams; weight of contained gold, 7.7759 grams (¼ ounce); diameter, 26.53 millimetres (mm) and gauge 1.82 mm. Specifications for the 22-carat gold coin are: gold, 91.66 per cent; copper, 7.34 per cent; silver, 1.00 per cent; weight, 16.96 grams; weight of contained gold, 15.5517 grams (½ ounce); diameter, 24.49 millemetres and gauge 1.96 millimetres. The 14-carat gold coin was sold for $105 and the 22-carat for $150. The semi-annual report of the Olympic (1976) Act — Olympic Coins for the period October 1, 1976 to March 31, 1977, listed 572 387 uncirculated 14-carat gold coins and 335 779 proof 22-carat gold coins sold. These were the first $100 "legal tender" gold coins issued by the Canadian government.

In 1976 the Republic of South Africa was, by far, the leading gold-producing country, followed by the U.S.S.R., Canada and the United States. Other significant producers were Ghana, Papua-New Guinea, Rhodesia, the Philippines and Australia. Smaller producing countries were Brazil, Colombia, Mexico, Peru, Dominican Republic, Japan and Zaire.

Consolidated Gold Fields Limited, which holds a large interest in South African gold mining, in its report *Gold 1977* reported gold production in the noncommunist world for 1976 at 965.8 tonnes, equivalent to 31.05 million ounces, compared with 956.8 tonnes (30.76 million ounces) in 1975. In 1976, gold production in the Republic of South Africa was 713.4 tonnes, about the same as in 1975. South African gold production in 1976 was 73.9 per cent of the noncommunist world total, compared with 74.5 per cent in 1975. Canada accounted for 5.4 per cent of the non-communist world gold production in 1976. Consolidated Gold Fields estimated gold production in the U.S.S.R. for the years 1976 and 1975 at 443.6 tonnes and 407.9 tonnes, respectively, and for other communist countries for this period at 20 tonnes each year. Estimated world gold production was 1 429.4 tonnes, an increase of 3.2 per cent above 1975. On a world basis South Africa accounted for 49.9 per cent of the world total in 1976, Russia 31.0 per cent, Canada 3.7 per cent and the United States 2.2 per cent. Table 2 shows the U.S. Bureau of Mines figures for world gold production which estimate U.S.S.R. gold production for 1975 and 1974 at 233.3 tonnes and 227.0 tonnes respectively; considerably below the 407.9 tonnes and 420.7 tonnes estimated by Consolidated Gold Fields. The general consensus is that the U.S.S.R. will continue to increase its gold output over the next few years.

The world's major centres for the distribution of gold supplies are London, where gold sales are handled through member companies of the London Gold Market, and Zurich, Switzerland, where they are handled through bullion dealers. The Republic of South Africa is one of the major suppliers of gold to these centres and in 1976 made all its gold production available to the market, plus four tonnes from its official reserves to meet balance-of-payments obligations. This does not include the reduction of gold from its official reserves through "swap arrangements".

According to *Gold 1977* the market supply of 1 448 tonnes of new gold in 1976 was appreciably above the 1 121 tonnes of the previous year. Production of 965.8 tonnes of gold in the noncommunist world was 0.9 per cent greater than in 1975. Sales from the communist countries were up substantially in 1976 and were estimated by Consolidated Gold Fields to be 412 tonnes. Some gold was sold by the People's Republic of China, which shipped 80.8 tonnes of gold to the United Kingdom in the latter part of 1976 for disposal through the London Gold Market. It was estimated that 60 tonnes of this amount were sold in 1976. Most of the remaining gold was from the U.S.S.R. and was sharply above the 1975 shipments. Official gold transactions added an additional 70 tonnes to the world market, which on the plus side included the 121 tonnes from the IMF sales, a reduction in the official holdings of South Africa by 4 tonnes, 10.5 tonnes for Canada's gold coin program and about 8.7 tonnes from other sources. These official sales were offset by official purchases by central banks of Colombia, India, Chile and some Middle East and Far East Countries totalling approximately 75 tonnes.

Trading in gold futures was carried out on five commodity exchanges in the United States: the Commodity Exchange Inc. (Comex) of New York, the International Monetary Market (IMM) of Chicago, the Chicago Board of Trade (CBT), the New York Mercantile Exchange (NYME) of New York and the Mid America Commodity Exchange of Chicago. The first two listed exchanges were the most active. Gold futures are also traded on the Winnipeg Commodity

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 2. World gold production, 1974-1975

	1974	1975[p]
	(grams)	
North America		
Canada	52 825 896	51 433 114
United States	35 050 071	32 728 696
Other countries	7 565 579	22 916 326
Total	95 441 546	107 078 136
South America		
Colombia	8 248 486	9 311 323
Brazil	7 629 372	7 775 869[e]
Chile	3 695 995	4 063 700
Peru	3 162 011	2 702 892
Bolivia	1 293 905	1 656 011
Other countries	1 197 670	1 427 432
Total	25 227 439	26 937 227
Europe		
U.S.S.R.[e]	227 005 381	233 276 076
Yugoslavia	5 505 315	5 007 660
Sweden	2 125 985	2 177 243[e]
Romania[e]	1 866 209	1 866 209
Other countries	2 310 833	2 652 567
Total	238 813 723	244 979 755
Asia		
Philippines	16 681 977	15 606 978
North Korea[e]	4 976 556	4 976 556
Japan	4 345 996	4 463 007
India	3 144 997	2 844 009
Other countries	5 644 628	5 055 621
Total	34 794 154	32 946 171
Africa		
Republic of South Africa	758 557 906	713 445 952
Ghana	17 623 759	16 294 769
Rhodesia	15 551 738	17 106 912
Zaire	4 062 207	3 210 408
Other countries	2 753 218	2 379 198
Total	798 548 828	752 437 239
Oceania		
Papua — New Guinea	21 543 388	18 418 795
Australia	16 239 965	15 992 972[e]
Fiji	2 142 719	2 138 177
Other countries	173 651	180 400
Total	40 099 723	36 730 344
World Total	1 232 975 413	1 201 108 872

Sources: U.S. Bureau of Mines, Mineral Trade Notes, September 1976; Statistics Canada.
[p]Preliminary; [e]Estimated.

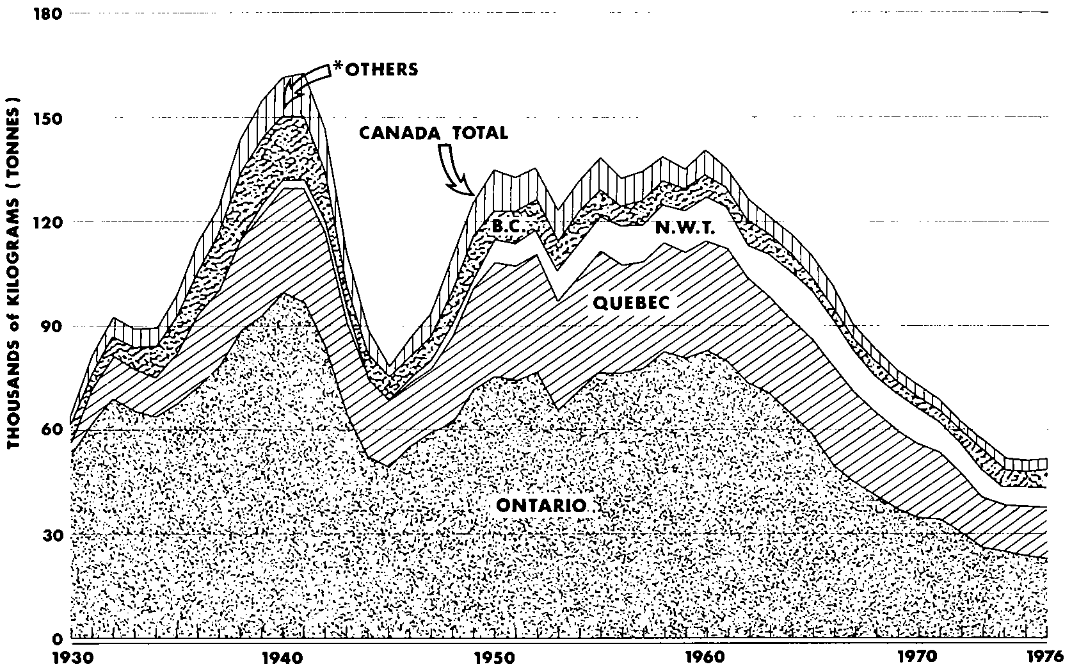
Exchange in 400 and 100 ounce contracts. The Hong Kong exchange is developing into an important outlet for gold sales.

As a result of the problem created by the low gold price, an initiative was taken by the Canadian gold producers to form "The Gold Institute/L'Institut de L'Or", which is patterned after The Silver Institute, a world organization based in Washington, D.C., which has been successful in promoting the interests of the silver industry. The Institute shares administrative offices with The Silver Institute in Washington, D.C., but the former's financial office is located in Toronto, Ontario. Membership at present includes all Canadian lode gold mines and some of the major Canadian mining companies who produce gold as a byproduct. It is hoped to make the Institute international, with representation from other gold-producing countries, and to encourage membership by fabricators and other groups having an interest in the gold industry. Initially it is being financed by an assessment based on the number of ounces of gold produced by member companies.

The objectives of the organization are: to encourage the development and use of gold and gold products, to help develop markets for gold and its products, foster research and development related to the present and prospective uses of gold, spread knowledge and understanding of the uses of gold, develop methods for improving the welfare of the gold industry, and collect and publish statistics and other information about production, distribution, marketing, consumption and the uses of gold and gold products.

Efforts by representatives of producers, users, research scientists, educators, mercantilists and government agencies led to the formation of the International Precious Metals Institute (IPMI) in 1976. IPMI is chartered in the State of New York as a non-profit organization to encourage the exchange of information and technology, to publish data and statistics, to conduct educational meetings and to promote the efficient use of all precious metals.

GOLD PRODUCTION by PROVINCES



* OTHERS = NFLD., N.S., N.B., MAN., SASK., ALTA., Y.T.
DATA SOURCE: STATISTICS CANADA

Canadian developments

Atlantic Provinces. All gold produced in the Atlantic Provinces in 1976 was derived as a byproduct of base-metal ores. The generally low gold price in 1976 restricted exploration activity in the former gold-producing areas in Nova Scotia.

Quebec. The installation of a new flotation section and a secondary grinding unit at the mill of Agnico-Eagle Mines Limited in the latter part of 1975 significantly improved the overall gold recovery, which increased from 82.14 per cent in 1975 to 90.19 per cent in 1976. These additions to the plant also enabled the mill to operate near its designed capacity of 910 tonnes a day. The company carried out an aggressive exploration and development program on the upper levels of the mine to prepare this section for production. Underground diamond drilling to test the area below the 550-metre level confirmed the existence of the ore zone to the 686-metre level. The shaft is being deepened by 335 metres to the 904-metre level and seven new levels will be established. Work on this project was started about the middle of 1976 and is expected to be completed in the latter part of 1977. In its annual report the company stated that it cost $92.27 to produce an ounce of gold in 1976.

Camflo Mines Limited completed the installation of ore- and waste-pass systems from the 975-metre level to the 732-metre level, and is developing the lower levels for production. According to a statement in the 1976 annual report it cost the company $61 to produce an ounce of gold. East Malartic Mines, Limited, prepared the newly developed orebodies at the old Barnat mine for production and installed new surface facilities at its mill in order to treat Barnat ore. Lamaque Mining Company Limited continued using load-haul-dump equipment to explore, develop and mine flat orebodies in the north end of the property. At Sigma Mines (Quebec) Limited the ore pass system was completed to the bottom level (40th) and development undertaken on the lower levels. Falconbridge Copper Limited, Opemiska Division, expects to bring its Cooke mine in the Chibougamau District into production in the latter half of 1977. Estimated reserves at this mine are 503 000 tonnes averaging 1.46 per cent copper and 10.28 grams of gold a tonne. Ore reserves at the

Table 3. Canada, gold production, 1965, 1970 and 1974-76

	Auriferous Quartz Mines		Placer Operations		Base-metal ores		Total	
	(grams)	(%)	(grams)	(%)	(grams)	(%)	(grams)	(%)
1965	92 031 269	82.1	1 387 153	1.2	18 741 680	16.7	112 160 102	100.0
1970	58 591 610	78.2	228 890	.3	16 094 525	21.5	74 915 025	100.0
1974	37 725 749	71.4	304 907	.6	14 795 240	28.0	52 825 896	100.0
1975	37 529 456	73.0	335 077	.6	13 568 581	26.4	51 433 114	100.0
1976p	37 664 000	71.8	426 000	.8	14 354 000	27.4	52 440 000	100.0

Source: Statistics Canada. Compiled by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
p Preliminary.

Table 4. Canada, gold production, average value per gram and relationship to total value of all mineral production, 1965, 1970 and 1974-76

	Total production	Total Value	Average value per gram[1]	Gold as per cent of total value of mineral production
	(grams)	($ Cdn.)	($ Cdn.)	(%)
1965	112 160 102	136 051 943	1.21	3.7
1970	74 915 026	88 057 464	1.18	1.5
1974	52 825 896	263 794 245	4.99	2.3
1975	51 433 114	270 830 389	5.27	2.0
1976p	52 440 400	207 796 000	3.96	1.4

Source: Statistics Canada.
[1] Value not necessarily based on average gold price for 1976.
p Preliminary.

Horne Mine of Noranda Mines Limited were exhausted, and the mine closed in July 1976. This mine came into production in 1927 and has been a major contributor to the production of byproduct gold. Noranda discontinued development at its Chadbourne gold property near the Horne mine because of the unfavourable gold price. In 1976 Patino Mines (Quebec) Limited, a substantial producer of byproduct gold, operated at 54 per cent of mill capacity because of the depressed copper price. Campbell Chibougamau Mines Ltd. signed a new two-year labour agreement with the United Steelworkers of America on August 31, 1976 and the Henderson and Cedar Bay mines were in production at year-end on a one-shift-a-day basis.

The generally unfavourable economic climate for the gold industry in 1976 drastically reduced expenditures for exploratory work on gold prospects. Darius Gold Mines Inc., a private company, continued its underground exploration program on the former O'Brien mine in the Cadillac district. Long Lac Mineral Exploration Limited carried out a diamond drilling program on the optioned property of Thompson Bousquet Gold Mines, Ltd., and located two mineralized zones to the south of the large low-grade zone. The company also acquired a substantial interest in the property of Silverstack Mines Ltd. in 1976.

Ontario. Total gold production in Ontario in 1976 was 22 830 000 grams, slightly lower than that of 1975. The 12 gold mines that operated in the province in 1976 accounted for 91.9 per cent of the provincial total, with the balance derived from base-metal mining.

Campbell Red Lake Mines Limited in the Red Lake district maintained its position as the leading lode gold mine producer in Canada. Increased costs of labour and supplies, and a sharp reduction in the price of gold, forced Bulora Corporation Limited to close its Red Lake district gold mine, the former property of Madsen Red Lake Gold Mines, Limited. To comply with air pollution requirements established by the Ontario Ministry of Environment, Dickenson Mines Limited is installing an arsenic-bagging plant to remove the arsenic trioxide emitted from its roasting plant. The plant is expected to be in operation about mid-June 1977. The Ross mine at Holtyre and the main Hollinger property adjoining the Schumacher mine in Timmins, both owned by Hollinger Mines Limited, were sold to Pamour Porcupine Mines Limited, in June 1976, for a reported purchase price of $600 000. The mill at the Ross property was shut down and the ore trucked to the Schumacher concentrator of Pamour in Timmins for treatment. Hollinger retained its optioned New Kelore Mines Limited property adjoining the Ross mine. Increased costs of labour, supplies and services, and particularly the low gold price during the middle of the year, placed the four operating mines of Pamour in the Timmins area in serious financial difficulties. To offset these adverse factors the company reduced its labour force by about 30 per cent during the year and phased-out the mining of the lower grade ore and ore blocks of better grade,

Table 5. International Monetary Fund, gold auctions, 1976

Date of Sale in 1976	Average bid price or common price[1]	Amount of gold sales	Number of troy ounces for which bids rec'vd	Afternoon fixing price on London gold market on day of auction	Number of successful bidders	Total number submitting final bids
	$ U.S./ troy ounce	troy ounces		$ U.S./ troy ounce		
June 2	126.00[1]	780 000	2 368 000	126.90	20	30
July 14	122.05	780 000	2 114 000	122.20	17	23
September 15	109.40	780 000	3 662 400	111.25	14	23
October 27	117.71	779 220	4 214 400	117.85	16	24
December 8	137.00[1]	780 000	4 307 200	135.65	13	25
Total gold sales in 1976		3 899 200				

[1]Common price — all successful bidders pay the same price as the lowest accepted bid price for gold received.

but with high operating costs. An improvement in the gold price in the latter part of the year eased the financial problems somewhat. The management agreement between Willroy Mines Limited and Upper Canada Resources Limited dated October 19, 1970 whereby Upper Canada took over management control of the Macassa mine of Willroy Mines was terminated on August 20, 1976. Rengold Mines Ltd. brought its 270-tonne-a-day gold property, the former producing Renabie gold mine near Missinabie, into production in January, but was forced to close the mine in June because of financial difficulties and the drop in the gold price. Mount Jamie Mines (Quebec) Limited installed a small gravity mill at its optioned gold property in the Red Lake district and operated the mill for a short period in late November and early December 1976, treating 500 tonnes and recovering 6 511 grams of gold. The property is expected to resume production in the spring of 1977.

Amoco Canada Petroleum Company Ltd., decided to undertake an underground exploration program to evaluate further its Detour Lake gold discovery in northeastern Ontario. Initial plans call for a 762-metre decline to the 122-metre level, 305 metres of drifting and crosscutting and 6 096 metres of diamond drilling. Preliminary surface diamond drilling has indicated a zone containing 9 070 000 tonnes with an average grade of 6.3 grams of gold a tonne. Ego Mines Limited is carrying out an underground and surface exploration program on its copper-gold property near Wawa. Kerr Addison Mines Limited is exploring the adjoining optioned gold properties of Arjon Gold Mines Limited and Sheldon-Larder Gold Mines, Limited, by driving a long crosscut from its 1 173-metre level into these properties, followed by an underground diamond-drilling program. During the period of lower gold prices in 1976 work on this projected area was suspended, but diamond drilling was resumed at year-end when the gold price improved. Some exploratory work consisting largely of geological mapping, and surface diamond drilling was carried out on gold properties in other mining areas. Exploration in Ontario in 1976 was adversely affected by the sharp decline in the gold price, problems related to inflation, and difficulty in raising venture capital.

Prairie Provinces. Virtually all gold produced in the prairie provinces was recovered as a byproduct from the mining of base-metal ores. A small amount of gold was recovered by gravel-washing plants on the North Saskatchewan River, near Edmonton. Exploratory work on gold properties in the prairie provinces in 1976 was limited.

British Columbia. The major portion of the gold produced in British Columbia in 1976 was recovered as a byproduct of base-metal mines, mainly from the treatment of copper ores. Dusty Mac Mines Ltd. exhausted its ore reserves and closed its mine in June 1976. The ore had been custom-treated at the concentrator of Dankoe Mines Ltd. and the concentrates produced were shipped to Cominco Ltd.'s smelter at Trail for the recovery of gold and silver. Northair Mines Ltd. began production in May 1976 at its 270-tonne-a-day concentrator located near Brandywine Falls, about 110 kilometres north of Vancouver. This is the first new metal mine to come into production in British Columbia since the copper mines of Lornex Mining Corporation Ltd. and Gibraltar Mines Ltd. were brought into production in 1972. The Northair mine is a vein-type deposit, and its estimated reserves have been reported to be 410 200 tonnes averaging 13 grams of gold a tonne, 9 grams of silver a tonne and 5.39 per cent combined lead and zinc. Three products are obtained; a gold and silver gravity concentrate which is poured into gold-silver bars, a zinc concentrate and a lead concentrate. A small percentage of copper in the ore may also be recovered. Some placer gold was recovered from the Cariboo and Atlin districts.

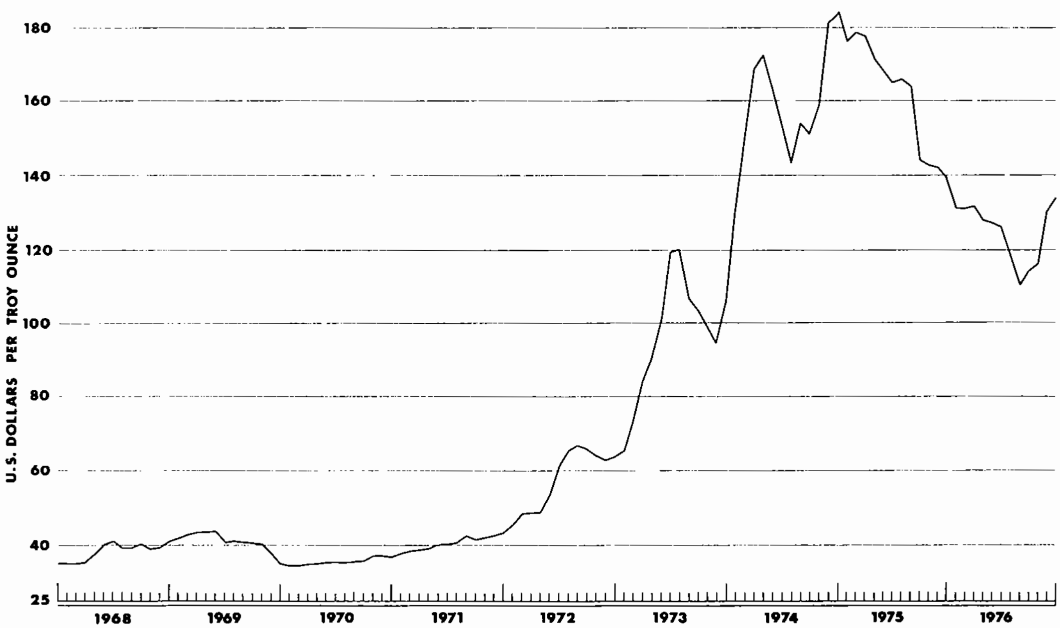
Yukon Territory. There was considerable activity in all of the older placer districts in the Yukon Territory in 1976. Claymore Resources Ltd. carried out an extensive program, testing its ground in the recently discovered placer deposits in the Ladue River district on the Alaska-Yukon boundary about 48 kilometres north of the Alaska highway. Other properties in the area were also being explored.

Northwest Territories. Cominco Ltd. completed sinking its new shaft at the Con Mine, near Yellowknife, at year-end. Hoisting and rock-handling facilities have to be installed and the shaft is expected to be in full operation in the latter half of 1977. The new shaft was required to mine more efficiently the ore developed in the lower sections of the mine. Ore reserves at the Con-Rycon complex at the end of 1976 were estimated at 1 334 000 tonnes averaging about 20.3 grams a tonne. The mill capacity was increased from 410 to 590 tonnes a day. Giant Yellowknife Mines Limited completed mining its A-1 pit and is preparing three smaller pits for production.

World developments

Republic of South Africa. In 1976 gold production in the Republic of South Africa was estimated by Consolidated Gold Fields at 713.4 tonnes, about the same as in 1975. Approximately one-third of the South African gold producers had operating costs of over $U.S. 100 an ounce of gold and, during the period of low gold prices in mid-1976, operated at a loss. Production was affected by a shortage of African labour but the situation improved towards the end of 1976. To offset increased costs of production, which rose by about 16 per cent in 1976; the sharp drop in the gold price, and the effects of labour shortage, the trend towards mining lower grade ores had to be reversed. The South African mines are highly labour-intensive and in the past have had to rely on expatriate labour. The source of labour supply has changed drastically and South Africa and Transkei now account for about 49 per cent of the African labour force, compared with only 23 per cent in 1974. There are now virtually no Malawian workers employed at the mines, despite the fact that country was once a major source of supply. The workers from Mocambique have declined from 22 per cent to 10 per cent of the labour force. Lesotho is a large contributor to the work force and accounts for

LONDON GOLD PRICES
MONTHLY AVERAGE
A.M. and P.M. FIXINGS



DATA SOURCE: SHARPS, PIXLEY LIMITED.

about 24 per cent of the total. Labour recruitments also come from Botswana and Rhodesia. A large factor in the increased operating costs has been the higher pay granted to the African miners. Higher wages have enabled the South African mine operators to recruit labour from within the country and have done much to solve labour shortages. To encourage stability in the labour force, some of the mines are taking steps to increase the housing available to the families of skilled employees. Negotiations carried on between the Mine Workers' Union and the Chamber of Mines of South Africa for the introduction of a five-day week reached a compromise agreement whereby the mine workers will work 11 days each two weeks, effective April 1, 1977.

The large increase in labour costs has forced the mine operators to use their African labour more efficiently. The operators have increased the use of mechanical equipment and adopted improved mining methods. They are also carrying out tests on mechanical equipment that can be used to mine narrow veins without blasting. Success in the development of mechanical equipment will reduce labour requirements and substantially lower the dilution factor in ore mined.

The Union Corporation Limited expects to have its 2 500-tonne-a-day Unisel mine in production in 1978. The 4 700-tonne-a-day mine of Deelkraal Gold Mining Company, in which Consolidated Gold Fields of South Africa and Consolidated Gold Fields of the United Kingdom have a substantial interest, is scheduled for production in 1980. Elandsrand Gold Mining Company Ltd. of Anglo-American Corporation of South Africa Ltd. expects to have its 4 500-tonne-a-day mine in production in 1981. All mines have experienced a sharp escalation in construction costs.

The South African Reserve Bank acts as the country's central bank and as the selling agent for the gold producers. Payments to the mines are made in two parts, an immediate payment to the mines at the official gold price on receipt of gold, followed by the premium obtained when the gold is sold on the open market. When the amendments are made to the IMF agreement the mines will receive full payment on receipt of goid.

Gold output in the Republic of South Africa is expected to remain relatively stable in the next two to three years. Production should increase when the three large mines now under development come on stream but the additional production could be offset by the closure of some marginal mines if there is a marked decline in the gold price.

United States. Gold production in the United States was estimated at 32 036 kilograms in 1976 by the United States Bureau of Mines, a decline of 1.9 per cent from the 32 658.6 kilograms produced in 1975. Byproduct gold, mainly from the treatment of porphyry copper ores increased by about 3 per cent in 1976 and accounted for about 36 per cent of the total output. Except for minor amounts of gold recovered from placer deposits, mainly in Alaska, lode gold mines accounted for the remainder of the gold production.

Homestake Mining Company, the largest gold producer in the United States milled 1 504 257 tonnes and recovered 9 906.0 kilograms of gold from its mine at Lead, South Dakota, about 4.5 per cent higher than in 1975. The only other major lode-gold producer in the United States is the open-pit mine of Carlin Gold Mining Company, a wholly owned subsidiary of Newmont Mining Corporation, in Nevada. Cortez Gold Mines, an open-pit operation in Nevada, exhausted its reserves and closed in August 1976. Kennecott Copper Corporation was the major contributor to byproduct gold. The sharp drop in the gold price discouraged exploration for, and development of, gold properties in the United States. Recovery of gold by heap-leaching is becoming increasingly important in Nevada, Colorado, Montana, New Mexico and California. The United States is one of the major consumers of gold and had to

Table 6. Gold reserves of central banks and governments, June 30, 1976.

Country	Value in millions of dollars; gold valued at $ U.S. 42.22 per fine troy ounce	Tonnes Gold fine	(million oz)
United States	11 598	8 544.3	(274.7)
Federal Republic of Germany	4 966	3 658.5	(117.6)
France	4 263	3 140.6	(101.0)
Switzerland	3 514	2 588.8	(83.2)
Italy	3 483	2 565.9	(82.5)
Netherlands	2 294	1 690.0	(54.3)
Belgium	1 781	1 312.1	(42.2)
Portugal	1 170	861.9	(27.7)
Canada	916	674.8	(21.7)
Japan	891	656.4	(21.1)
United Kingdom	888	654.2	(21.0)
Austria	882	649.8	(20.9)
Spain	602	443.5	(14.3)
Republic of South Africa	540[1]	397.8	(12.8)
Others	5 039	3 712.2	(119.4)
International Monetary Fund	6 448	4 750.2	(152.7)
Bank for International Settlements	290	213.6	(6.9)
Estimated Total, World[2]	49 565	36 514.6	(1 174.0)

Sources: Value from *Federal Reserve Bulletin* (U.S.) December, 1976; tonnes of gold calculated by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa. [1]Reflects Republic of South African Reserve Bank sale of gold, spot and repurchased forward. [2]Excludes holdings of U.S.S.R., other Eastern European countries and the People's Republic of China.

Table 7. Average annual price of gold 1965, 1970 and 1974-76

	London Gold Market[1]		Royal Canadian Mint[2]
	$U.S.	Equiv. $Cdn (per troy ounce)	$Cdn.
1965	37.76	40.82	37.73
1970	35.97	37.55	36.56
1974	159.259	155.755	41.18
1975	161.018	163.781	43.22
1976	124.836	123.107	39.85

[1]Annual average of London Gold Market afternoon fixing price, as reported by Sharpes Pixley Ltd. [2]Annual average of the Royal Canadian Mint weekly published buying price.

make substantial imports of gold in 1976, mainly from Canada, Switzerland (mostly South African origin) and the U.S.S.R. Secondary recovery of gold in the United States is also an important source of the metal.

Dominican Republic. Negotiations carried on between the government of the Dominican Republic and Rosario Resources Corporation and J.R. Simplot, resulted in the two companies each selling 13 per cent of their interest in Rosario Dominicana S.A. to the Dominican Republic for a payment of $3 697 044 to each company. The Dominican Republic now owns 46 per cent of the company and the two companies each hold 27 per cent. The major asset of Rosario Dominicana is the 7 260-tonne-a-day Pueblo Viezo open-pit gold mine operation located in the province of Sanchez Ramirez in the north-central region of the Dominican Republic. In 1976 the Pueblo Viezo mine produced 12 868.7 kilograms of gold and 28 220.7 kilograms of silver from the treatment of 2.62 million tonnes of ore, making it the largest gold producer in the Western Hemisphere. Ore reserves at the end of 1975 were reported to be 26.5 million tonnes of oxide ore averaging 4.32 grams of gold and 23.3 grams of silver a tonne. Drilling has outlined an underlying sulphide zone containing 21.1 million tonnes averaging 1.4 per cent zinc, 0.14 per cent copper, 3.57 grams of gold and 26.1 grams of silver a tonne. The company reports this zone is not economic under present technology, but research on methods to recover the metals is being carried out. Discussions have been held with the Dominican government on the development of gold discoveries on the Los Cacoas concession surrounding the Pueblo Viezo property.

Australia. Acting on a recommendation made by the Industries Assistance Commission as a result of their review of the gold industry during 1974-75, the Australian government on August 2, 1976 decided to phase out, over the next five years, the income tax exemption currently enjoyed by the gold producers. The measure was introduced in 1924 as an emergency action and remained in force until the Commission decided that gold mines should be treated on the same basis as any other mineral producers. Following strong representations by affected groups, the Australian government referred the matter back to the Industries Assistance Commission for a further review of the gold industry.

The sharp drop in the gold price forced some gold mines, mainly in the Kalgoorlie district of Western Australia, to suspend operations in 1976. However, at the Telfer gold property in the northwestern part of Western Australia the owners continued with their construction program to bring it into production in 1977. Newmont Proprietary Limited, a subsidiary of Newmont Mining Corporation, has a 70 per cent interest in the property and Dampier Mining Company Limited, a subsidiary of Broken Hill Proprietary Company Limited; has a 30 per cent interest. This is the first gold mine of any size found in Australia in over 40 years. Reserves, which will be mined by open-pit methods, are estimated to be 3 810 000 tonnes averaging 9.60 grams of gold a tonne. Daily mill capacity will be 1 220 tonnes. Because of the remote location of the property, a fully integrated community is being constructed.

Early in 1976, Kalgoorlie Lake View Pty. Ltd. and Homestake Mining Company of the United States formed the partnership Kalgoorlie Mining Associates to mine gold in the State of Western Australia. Homestake has a 48 per cent interest in the company. The depressed gold price forced the partnership to operate its Mt. Charlotte Mine at a reduced tonnage to lower its operating costs. A study was being made to determine if costs could be lowered by improving operating procedures, and also to assess the trend in the gold price. During the year, 590 620 tonnes averaging 4.18 grams of gold a tonne were treated to yield 2 812 780 grams of gold. Mulga Mines Proprietary Limited, a subsidiary of Anglo American Corporation of South Africa Ltd., has an approximate 74 per cent interest in the Blue Spec Mine, a small high-grade gold and antimony mine in Western Australia which came into production in April 1976.

Brazil. Anglo American Corporation do Brazil Limited, a subsidiary of Anglo American Corporation of South Africa, acquired a 49 per cent interest in Mineracao Morro Velho S.A., a company operating gold mines in Minas Gerais State. Anglo American has the financial and technical resources to increase the productivity of the mine and to initiate extensive exploration programs. About 50 per cent of Brazil's gold output of 11 600 kilograms is produced by Mineracao Morro. The company, in conjunction with others, is exploring the extensive auriferous conglomerates in the State of Bahia.

Costa Rica. A new company, Comiesa Corporation, was formed in 1976 to take over the holdings of Esperanza Mines Corporation, a wholly owned subsidiary of Bulora Corporation Limited. Comiesa turned over 50.1 per cent of its interests to a capital partner who assumed the responsibility of providing management and funds needed for equipment and underground development. Milling was suspended in September 1976 to allow the company to put all its resources into exploration and development. A number of mining companies are conducting exploratory programs in Costa Rica.

Nicaragua. Noranda Mines Limited holds a 60.5 per cent interest in the Empresa Minera de el Setentrion, a producing gold mine in Nicaragua. In 1976, 111 600 tonnes of ore were treated averaging 15.08 grams of gold a tonne. Considerable exploratory and development work is being done on other gold properties in the country by various companies.

Papua-New Guinea. Papua-New Guinea is a substantial producer of gold, mainly as a byproduct of the treatment of the open-pit copper ore of Bougainville Copper Limited. Production from this property was 19 826 kilograms in 1976. Some gold is also recovered by other small operators.

Philippines. In 1975 the Central Bank of the Philippines began the construction of a gold and silver refinery designed to refine 18 660 kilograms of gold and 14 000 kilograms of silver a year. The refinery, which is scheduled for completion in early 1977, will be able to process the Philippine gold output. The sharp drop in the gold price severely affected the profitability of the gold operations and some mines were forced to suspend operations. In August the gold producers approached the government for restoration of a gold subsidy program and asked for a guaranteed price of $160 an ounce, the price considered necessary to maintain a viable gold industry. At year-end the government had not made any decision on granting a subsidy.

France. Mines et Produits Chimiques de Salsigne operates a gold property in southern France, and in 1976 recovered 1 585.8 kilograms of gold. The company also produced about 8 000 tonnes of arsenious trioxide from its gold ore in 1976, plus some bismuth, copper and sulphuric acid.

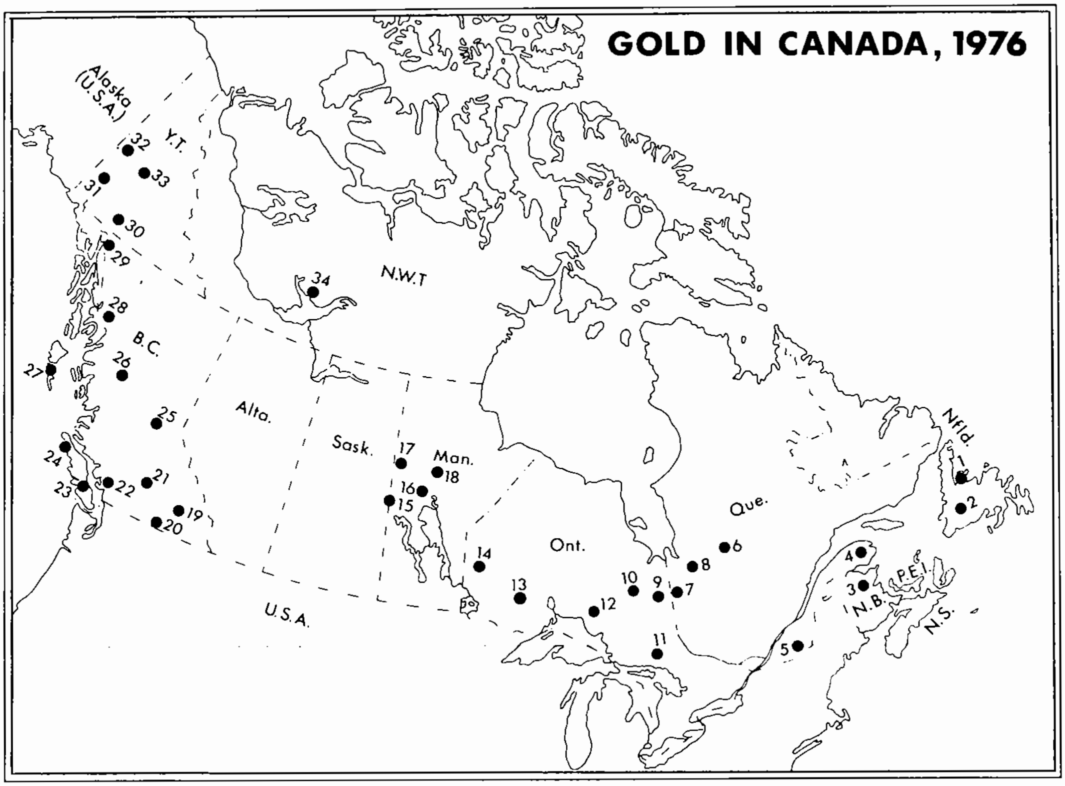
U.S.S.R. Detailed information on the gold industry in the U.S.S.R. is not available. It has been estimated that about two-thirds of the country's gold production comes from the northeastern district, mainly from placer deposits. Gold is recovered from placer deposits, the major source of U.S.S.R. gold output; lode mines and as a byproduct from base-metal production, mainly copper ores. The consensus is that gold production in the U.S.S.R. will increase over the next few years, but reports of a decline in placer reserves could result in lower production from this source and slow the trend towards increased output.

International Monetary Fund

At the meeting of the Interim Committee of the Board of Governors of the International Monetary Fund (IMF) held in Jamaica on January 7-8, 1976, an agreement was reached on all aspects of a major international monetary package. Among other things, the Agreement called for a reduction in the role of gold in the international monetary system, including the disposition of part of the IMF's own holdings of gold, a new system of exchange arrangements under which controlled floating currency would be legalized and the IMF quotas would be increased by one-third. To implement terms of the Agreement reached at Jamaica, amendments to Articles of Agreement of the IMF are required. Such amendments have been drawn up and have been submitted to member countries for their approval. When these amendments become effective, the function of gold as the unit of value of the Special Drawing Rights (SDR) will be eliminated and the official price of gold will be abolished. Member countries will then be free to deal in the gold market and among themselves. At present members can sell gold on the open market, but cannot add to their reserves through market purchase.

The most important phase of this agreement as to its effect on the world's gold mining industry is the sale of part of the gold held by the IMF. The meeting agreed that an immediate start be made on the implementation of the "Gold Agreement" reached at the Committee's meeting held in Washington, D.C. on August 31, 1975 whereby 777.6 tonnes (25 million ounces) of gold from the IMF gold reserves would be offered for sale on the open market. Profits derived from such sales are to be used to establish a trust fund to assist developing countries. It was agreed that the gold would be made available in public auctions according to an appropriate timetable over a four-year period.

In May 1976, the IMF announced the mechanics for the sale of gold. Over the first two years of the proposed four-year period, one-half, or 388.8 tonnes, of gold would be made available for public auction at intervals of about six weeks. Arrangements for the sale of the second 388.8 tonnes would be announced towards the end of the first two-year period. The main conditions of the bid format were: bids must be in multiples of 400 troy ounces; the minimum bid must be 2 000 ounces, which later was reduced to 1 200 ounces; the bid price per ounce of gold must be stated in U.S. dollars; and a deposit of $U.S. 50 000 must accompany each bid. Initially the "Dutch" auction system was used; that is, gold was awarded to all successful bidders at the same price as the lowest acceptable bid price for an ounce of gold. Later the



Gold Producers, 1976
(numbers refer to numbers on map above)

Newfoundland
(1) Consolidated Rambler Mines Limited (a)*
(2) ASARCO Incorporated (Buchans Unit) (a)

New Brunswick
(3) Heath Steele Mines Limited (a)

Quebec
(4) Gaspé Copper Mines, Limited (a)
(5) Sullivan Mining Group Ltd. (a)
(6) Chibougamau district
Campbell Chibougamau Mines Ltd. (a)
Falconbridge Copper Limited (Opemiska Division) (a)
Patino Mines (Quebec) Limited (Copper Rand Division) (a)
(7) Noranda-Rouyn district
Falconbridge Copper Limited (Lake Dufault Division) (a)
Noranda Mines Limited (a)
Malartic — Val d'Or district
Camflo Mines Limited (b)
East Malartic Mines, Limited (b)
Lamaque Mining Company Limited (b)
La Société minière Louvem inc. (a)
Manitou-Barvue Mines Limited (b)
Sigma Mines (Quebec) Limited (b)
(8) Matagami district
Agnico-Eagle Mines Limited (b)
Mattagami Lake Mines Limited (a)
Orchan Mines Limited (a)

Ontario
(9) Larder Lake Mining Division
Kerr Addison Mines Limited (b)
Pamour Porcupine Mines, Limited (Ross mine) (b)
Willroy Mines Limited (Macassa Division) (b)
(10) Porcupine Mining Division
Dome Mines, Limited (b)
Pamour Porcupine Mines, Limited (Nos. 1, 2 and 3 mines) (b)
Pamour Porcupine Mines, Limited (Schumacher Division, McIntyre mine) (a & b)
(11) Sudbury Mining Division
Falconbridge Nickel Mines Limited (a)
Inco Limited (a)
(12) Thunder Bay Mining Division
Noranda Mines Limited (Geco Mine) (a)

*(a) Base metal; (b) Auriferous quartz; (c) Placer.

(13) Patricia Mining Division
Falconbridge Copper Limited (Sturgeon Lake Division) (a)
Mattabi Mines Limited (a)
(14) Red Lake Mining Division
Bulora Corporation Limited (Madsen Red Lake Division) (b)
Campbell Red Lake Mines Limited (b)
Dickenson Mines Limited (b)
Robin Red Lake Mines Limited (b)

Manitoba
(15) Hudson Bay Mining and Smelting Co., Limited (Flin Flon) (a)
(16) Hudson Bay Mining and Smelting Co., Limited (Snow Lake) (a)
(17) Sherritt Gordon Mines Limited (Fox Lake & Ruttan mines) (a)
(18) Inco Limited (a)

Saskatchewan
(15) Hudson Bay Mining and Smelting Co., Limited (a)

British Columbia
(19) Cominco Ltd. (a)
(20) Granby Mining Corporation (Phoenix Division) (a)
Dusty Mac Mines Ltd. (N.P.L.) (b)
(21) Brenda Mines Ltd. (a)
Similkameen Mining Company Limited (a)
(22) Northair Mines Ltd. (b)
(23) Western Mines Limited (a)
(24) Utah Mines Ltd. (Island Copper Mine) (a)
(25) Small placer operations (c)
(26) Granby Mining Corporation (Granisle Division) (a)
Noranda Mines Limited (Bell Copper mine) (b)
(27) Wesfrob Mines Limited (a)
(28) Newmont Mines Limited (a)
(29) Small placer operations (c)

Yukon Territory
(30) Whitehorse Copper Mines Ltd. (a)
(31) Small placer operations (c)
(32) Small placer operations (c)
(33) Small placer operations (c)

Northwest Territories
(34) Cominco Ltd. (Con mine) (b)
Giant Yellowknife Mines Limited (b)
Lolor Mines Limited (b)
Rycon Mines Limited (b)
Supercrest Mines Limited (b)

open price method was used; that is, the awards to the successful bidders were made at the price submitted by the bidder for an ounce of gold.

The first gold auction was held on June 2, 1976 and five auctions in all were held during 1976 in which 121.28 tonnes (3 899 200 ounces) were sold. Details of the gold auctions are listed in Table 5.

Along with the gold auctions of 777.6 tonnes, it was also agreed to restitute an equal amount of gold from the IMF gold reserves over the four-year period to member nations at the official gold price of 35 SDR an ounce in proportion to their quotas in the fund. The gold is to be restituted in four equal parts of 194.4 tonnes (6¼ million ounces) each near the end of each year. The IMF announced in December that the first restitution of the gold will be made early in January 1977.

On June 30, 1976 gold held by the Central Banks and the IMF stood at 36 514.6 tonnes. Table 6 shows gold quantities held by individual countries.

In March 1976 the Republic of South Africa arranged a swap deal whereby it arranged to sell spot gold to be repurchased at a later date. About 155 tonnes (5 million ounces) of gold was made available to a consortium of Swiss banks.

Prices

The decline in the gold price which began in 1975, caused by the failure of United States demand to meet expectations after the removal of the restrictions on U.S. citizens to hold gold, the sale of gold from the official reserves of the United States and the announcement by the IMF in August 1975 of its intention to dispose of one-third of its gold reserves, continued into 1976. The opening gold price on the London Gold Market for the year 1976 was $U.S. 140.35 an ounce, the high for the year. The effect IMF gold sales would have on the market created a period of uncertainty for the first nine months of the year. The price declined from its high for the year of $U.S. 140.35 on January 2 to $U.S. 135.80 following the announcement on January 8, 1977 that the IMF had reached an agreement on gold sales at its Jamaican meeting. Prices continued to decline, with short periods of price reversal on favourable market factors. At the first IMF gold auction on June 2, 1976 the accepted bid price was $U.S. 126.00, near the open market price. Following the gold auction, prices were comparatively stable until after the second auction, in which the acceptable bid was $U.S. 122.05. After this auction the gold price dropped sharply until a low of $U.S. 103.05 an ounce for the year was registered on August 31. The monthly averages of the afternoon fixing prices on the London Gold Market for the period July to October were $U.S. 114.48, $108.36, $111.29, and $112.98, respectively, the period for which low prices prevailed. The price recovered substantially from these lows when it was recognized that a strong demand for industrial gold usage had developed, and the market could absorb the extra gold from IMF sales. The average afternoon fixing price for gold on the London Gold Market for the month of December was $U.S. 133.88 an ounce. The average price of gold for the year 1976, based on the afternoon fixing price on the London market, was $U.S. 124.84, compared with $U.S. 161.02 in 1975.

Table 8. Principal gold (mine) producers in Canada — 1976 and (1975)

		Grade of Ore Treated						
Company and Location	Mill or Mine Capacity	Gold	Silver	Copper	Combined Lead and Zinc	Ore Treated	Gold Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(grams/ tonne)	(%)	(%)	(tonnes)	(grams)	
Newfoundland								
ASARCO Incorporated (Buchans Unit), Buchans	1 130 (1 130)	0.72 (0.75)	105.60 (103.88)	0.96 (0.95)	16.72 (16.46)	188 694 (210 466)	108 769 (127 058)	
Consolidated Rambler Mines Limited, Baie Verte	1 090 (1 090)	2.61 (2.06)	21.74 (19.54)	3.68 (3.20)	— (—)	187 284 (221 862)	362 107 (325 436)	
New Brunswick								
Heath Steele Mines Limited, Newcastle	3 630 (2 810)	0.62 (0.62)	77.83 (59.31)	0.99 (1.03)	6.38 (5.63)	1 052 568 (988 321)	207 305 (179 436)	No. 5 shaft to be in operation early in 1977.
Quebec								
Agnico-Eagle Mines Limited, Joutel	910 (910)	7.06 (7.99)	. . (. .)	— (—)	— (—)	313 467 (280 795)	2 001 302 (1 842 072)	Deepening shaft 335 metres to the 904-metre level.
Camflo Mines Limited, Malartic	1 130 (1 130)	6.69 (6.65)	. . (. .)	— (—)	— (—)	420 681 (413 788)	2 813 562 (2 753 209)	Developing lower levels.
Campbell Chibougamau Mines Ltd., Main, Cedar Bay and Henderson mines, Chibougamau	3 630 (3 630)	2.43 (1.85)	8.64 (7.85)	1.62 (1.31)	— (—)	132 996 (199 165)	262 296 (. .)	New two-year labour agreement signed August 31, 1976.
East Malartic Mines, Limited, Malartic	1 630 (1 630)	3.41 (3.51)	. . (. .)	— (—)	— (—)	543 564 (509 180)	1 791 063 (1 721 111)	Barnat mine prepared for production.
Falconbridge Copper Limited, Lake Dufault Division, Millenbach and Norbec mines, Noranda-Rouyn	1 360 (1 360)	0.82 (0.79)	41.49 (38.34)	3.09 (2.50)	3.44 (—)	458 447 (508 724)	264 473 (275 732)	Sinking Corbet shaft.

Falconbridge Copper Limited, Opemiska Division, Perry, Springer and Cooke mines, Chapais	2 720 (2 720)	0.60 (0.48)	12.55 (11.31)	2.01 (2.02)	— (—)	947 053 (863 635)	456 506 (311 035)	Preparing Cooke mine for production in 1977.
Lamaque Mining Company Limited, Val d'Or	1 900 (1 900)	4.17 (4.25)	. . (. .)	— (—)	— (—)	444 965 (425 089)	1 933 828 (1 708 576)	Developing "flats" in north end of property.
Lemoine Mines Limited, Chibougamau	363 (363)	5.18 (4.94)	96.69 (97.37)	4.35 (4.15)	10.40 (10.07)	88 237 (6 260)	378 716 (12 441)	Tune-up operations started in mid-November, 1975.
Mattagami Lake Mines Limited, Matagami	3 500 (3 500)	0.48 (0.48)	31.89 (29.49)	0.55 (0.62)	7.4 (7.3)	1 112 156 (1 166 370)	219 093 (143 076)	Driving exploration decline from 265-metre level to 610-metre level.
Noranda Mines Limited, Horne Division, Noranda	2 900 (2 900)	4.35 (5.07)	14.06 (. .)	1.40 (2.36)	— (—)	123 745 (256 060)	377 596 (1 009 557)	Mine closed on July 1, 1976.
Patino Mines (Quebec) Limited, Chibougamau	2 540 (2 540)	3.09 (1.95)	10.29 (8.50)	1.72 (1.67)	— (—)	516 356 (399 161)	1 229 676 (622 070)	Mill operated at 54% of capacity.
Sigma Mines (Quebec) Limited, Val d'Or	1 270 (1 270)	5.383 (5.21)	. . (. .)	— (—)	— (—)	452 536 (451 257)	2 341 594 (2 260 477)	Ore pass system completed.
Ontario								
Bulora Corporation Limited, Madsen Red Lake Division, Red Lake	720 (720)	. . (7.44)	. . (. .)	— (—)	— (—)	. . (124 935)	. . (878 549)	Mine closed in 1976.
Campbell Red Lake Mines Limited, Red Lake	720 (720)	22.94 (23.01)	. . (. .)	— (—)	— (—)	272 641 (271 755)	5 742 013 (5 761 235)	
Dickenson Mines Limited, Red Lake	430 (430)	13.98 (14.78)	1.65 (1.37)	— (—)	— (—)	74 283 (82 900)	963 244 (1 136 428)	Constructing arsenic bagging plant.

Table 8. (concl'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Treated: Gold	Grade of Ore Treated: Silver	Grade of Ore Treated: Copper	Grade of Ore Treated: Combined Lead and Zinc	Ore Treated	Gold Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(grams/ tonne)	(%)	(%)	(tonnes)	(grams)	
British Columbia (cont'd)								
Noranda Mines Limited, Bell Copper Division, Babine Lake	9 070 (9 070)	0.34 (. .)	. . (. .)	0.429 (0.46)	— (—)	1 925 257 (4 335 049)	296 136 (739 019)	Operations shut down for 29 weeks by a strike.
Northair Mines Ltd., Brandywine area	270	19.88	111.75	. .	2.67	47 555	563 657	Mill tune-up started in May, 1976.
Similkameen Mining Company Limited, Ingerbelle pit, Princeton	20 000 (20 000)	. . (. .)	. . (. .)	0.42 (0.46)	— (—)	6 355 738 (3 694 037)	1 107 284 (665 614)	
Utah Mines Ltd. Island Copper Mine Coal Harbour Vancouver Island	34 500 (34 500)	. . (. .)	. . (. .)	0.47 (0.48)	— (—)	12 246 998 (12 065 494)	1 430 760 (1 866 209)	
Western Mines Limited Buttle Lake Vancouver Island	1 000 (1 000)	3.09 (2.74)	169.37 (153.94)	1.19 (1.12)	9.15 (8.93)	269 294 (260 717)	695 474 (642 878)	Increased development work in 1976.
Yukon Territory								
Whitehorse Copper Mines Ltd. Whitehorse	2 180 (2 180)	. . (0.88)	. . (10.11)	1.69 (1.52)	— (—)	726 506 (669 555)	576 970 (579 458)	Mine closed for 70 days because of labour strike.
Northwest Territories								
Cominco Ltd. Con & Rycon mines Yellowknife	400 (450)	21.29 (18.86)	. . (. .)	— (—)	— (—)	137 040 (134 263)	2 798 909 (2 404 299)	Sinking of new shaft completed late in 1976; ore handling facilities to be installed.
Giant Yellowknife Mines Limited Yellowknife	910 (910)	9.15 (9.29)	. . (. .)	— (—)	— (—)	357 186 (310 040)	2 904 380 (2 527 033)	45 per cent of ore treated came from open-pit mine.

Lolor Mines Limited Yellowknife	14[1] (45)[1]	8.85 (9.09)	. . (. .)	— (—)	— (—)	5 332 (16 636)	42 052 (132 812)	Ore mined and milled by Giant Yellowknife.
Supercrest Mines Limited Yellowknife	71[1] (80)[1]	16.32 (15.87)	. . (. .)	— (—)	— (—)	25 897 (28 912)	372 744 (401 888)	Ore mined and milled by Giant Yellowknife.

Source: Company reports.
[1]Average daily tonnage milled.
— Nil; . . Not available.

Uses and consumption

Gold has been used traditionally as a monetary reserve by governments and central banks in the settlement of international balances, but since August 1971, when the President of the United States suspended the convertibility of the U.S. dollar into gold, it has not been used for this purpose. When the accord reached in Jamaica on May 8, 1976 on abolishing the official price of gold is finalized, the metal's use as an official reserve will disappear. However, its use as collateral in loans between countries may increase.

The major industrial uses of gold are in the jewellery trade, the electronics industry, dentistry and coinage. In the industrial field, emphasis has been placed on the development of technology leading to a more efficient use of gold, such as a thinner film in gold plating, selective and spot gold-plating, and duplex plating with a high-carat surface on a low-carat base. Other precious metals, mainly silver, platinum and palladium, can be used in place of gold in many of its applications.

Twenty-four carat gold is now being employed as a coating on glass windows used in the construction of new high-rise office buildings, mainly because of its thermal properties, but also for its aesthetic appearance (the head office building of the Royal Bank of Canada in Toronto used about 2 500 ounces of gold in gold-coated glass). Gold-coated or "gold-reflective" glass blocks out the sun's heat rays in the summer while admitting the light rays. Depending on the method of deposition and on use, an ounce of gold is required to cover between 400 to 1 000 square feet of glass. Research has shown that a new use for gold could develop as a casing for cylinders in the disposal of radioactive waste from nuclear power plants. In this application a nickel-steel alloy cylinder would be clad with a sheet of 24-carat gold which would protect the nickel alloy cylinder from deterioration and keep the radioactive waste permanently sealed.

According to figures contained in the Consolidated Gold Fields report the noncommunist world consumption of gold in 1976 increased substantially from 1 121 tonnes in 1975 to 1 448 tonnes in 1976. There was a sharp increase in jewellery consumption, smaller but significant increases in electronics, dentistry, other industrial and decorative uses, and medals, medallions and "fake" coins (coins generally containing the required gold but not considered legitimate issues) and a decrease in the mining of official coins.

The use of gold in the jewellery trade is largely a function of price and the purchasing power of the public. In the developed countries the price of gold is not the determining factor in gold jewellery purchases as design, special fashion factors and labour play an important part in the final price. The mark-up on contained gold in an item of jewellery in these countries can be over 300 per cent. The market in the developing countries generally demands jewellery of a high carat, usually 22-carat, and the mark-up is low, about 20 to 30 per cent. Gold jewellery in these countries is purchased partly because of its aesthetic appearance, but mainly as a storehouse of value.

There was a substantial increase in the importation of both gold bullion and gold jewellery into the Middle East and Turkey in 1976, a reversal to the trend in 1975 when hoarded gold in the form of jewellery and bullion was being sold. The major proportion of the gold was purchased by local inhabitants and migrant workers whose purchasing power had increased sharply because of the strong economy in this part of the world initiated by huge oil profits. It was estimated that about 400 tonnes of gold bullion and 80 tonnes of contained gold in jewellery were imported by Middle East countries. A large amount of gold was manufactured into 22-carat jewellery which is in demand in those countries. Most of the jewellery imports were from Italy.

Gold consumed in the jewellery industry in 1976 was estimated by Consolidated Gold Fields at 935.8 tonnes compared with 511.1 tonnes in 1975, an increase of 83 per cent. Italy was by far the largest manufacturer of gold jewellery, consuming 177.0 tonnes in 1976 compared with 71 tonnes in 1975. Turkey was next with 100.7 tonnes, followed by the United States, with 66.9 tonnes; Iran, 50.0 tonnes; Spain, 45.5 tonnes; Saudi Arabia and Yemen, 37 tonnes; Germany, 36 tonnes and Indonesia with 35 tonnes.

Most noncommunist countries reported small increases in the use of gold in electronics, and world consumption in 1976 was 72.1 tonnes compared with 63.6 tonnes in 1975. Japan surpassed the United States as the major user of gold in the electronics industry, consuming 23.1 tonnes, compared with 21.9 tonnes for the United States and 8.2 tonnes for Germany. Gold usage in dentistry in the noncommunist countries in 1976 was 70.2 tonnes compared with 64.3 tonnes in 1975. Consumption in most of the countries was about the same as the previous year, but the three major consumers, United States, Germany and Japan, had increases of 3 tonnes each. The consumption of gold for other industrial and decorative purposes in 1976 was 61.4 tonnes compared with 56.0 tonnes in 1975, the United States being responsible for the largest increase.

The Gold Institute / L'Institut de L'Or prepared a report on the official gold coinage issued in 1976 which showed that 46 countries issued a total of 96 coins of varying gold content for a total gold consumption of 133.7 tonnes (4 298 782 troy ounces). The krugerrand of the Republic of South Africa, a gold coin containing 31.1 grams (one ounce) of gold, comprised the bulk of the coins issued in 1976. In all, 2 900 087 krugerrands were issued, and they consumed 90.2 tonnes (2 900 087 ounces) of gold.

Other countries issuing gold coins in 1976 which consumed significant amounts of gold were Austria, Canada, Chile and the United Kingdom. These countries consumed a total of 38.9 tonnes of gold for coinage purposes.

According to the Report, *Gold 1977,* gold consumed in gold coins in 1976 was about 27 per cent below that of 1975, a drop in krugerrand sales being mainly responsible. In an effort to reverse declining krugerrand sales the International Gold Corporation (Intergold) of South Africa, the gold promotion arm of the Chamber of Mines of the Republic of South Africa, launched a well-financed campaign in the United States in the latter part of 1976 to promote the sale of the krugerrand to the United States public. At year-end sufficient time had not elapsed to measure the success of this promotional campaign.

Outlook

The normal commodity demand-supply relationship that exists for other metals does not at this time apply to gold because of its role as a metal included in the monetary reserves of many countries, a metal consumed by industry, and also purchased for speculative and hedging purposes. It is therefore difficult to make price projections. The improvement in the gold price that began in the latter part of 1976 continued in early 1977 and, for a time at least, began to show some stability in the range of $U.S. 140 to $U.S. 150 an ounce.

A number of factors may influence the trend of the gold price in the short term. The amendments to the Articles of Agreement of the International Monetary Fund are expected to be ratified by all member countries in the latter part of 1977 or early 1978. At this time the official role of gold in the monetary system will end. Central banks will be free to add to their gold holdings and it is expected that some central banks will make gold purchases. At present central banks can only dispose of gold from their official reserves. In the early part of 1977, as part of the agreement reached in Jamaica in January of 1976, the IMF restituted 194.4 tonnes (6.25 million ounces) of gold to member countries in proportion to their holdings in the IMF. Early reports indicated that little if any of this gold has reached the open market. Three more gold restitutions of equal amounts are to be made yearly and, depending on the price and the need by countries to satisfy outstanding obligations, some of this gold could be made available to the markets or to central banks through bilateral arrangements. Sales of gold by the U.S.S.R. cannot be predicted but its sales pattern could affect world prices. However, U.S.S.R. gold sales have generally been made in a manner that is most beneficial to the country's needs. It is expected that the U.S.S.R. will continue to sell gold on the open market to pay for wheat imports and capital needs and it could sell 150 to 300 tonnes a year over the next few years. The strong economy of the Middle East has increased the disposable income in the hands of the general public of that area and much of this money has been channelled into the purchase of high-carat gold jewellery. These purchases played a significant role in the increased consumption of gold jewellery and the subsequent increase in the gold price, and it is expected that this demand will continue in 1977.

The supply-demand relationship for gold was in comparatively close balance in 1976 and it is expected to continue in the short term. In 1977 the gold price could vary from $U.S. 135 to $U.S. 160 an ounce. Market forces will likely prevent prices from dropping significantly below the low range or rising above the high range. The increased industrial demand for gold was largely responsible for the rise in the price in the latter part of 1976 and early-1977 and the gold price appeared to have attained some stability in the price range of $U.S. 140 to $U.S. 150 an ounce. Speculative buying could force the gold price up to about $U.S. 160 an ounce, but at a higher level gold sales by the United States Treasury or central banks could probably take place, thus acting as a barrier to any sharp gold price rise. The strong demand for gold by industry in the latter part of 1976 is expected to continue in 1977 and no sharp decline in the gold price is expected. However, if the price of gold falls back to about $U.S. 135 an ounce some central banks would probably enter the market, that is, after the restrictions on buying gold are removed, to protect the value of their gold holdings. Speculative money would probably also be available at this price. There are large stocks of gold held by central banks which it is considered will not be dumped on the market but used mainly to establish some stability to the gold market, or they could be used to obtain funds to satisfy some pressing domestic or political need.

In the short-term outlook, gold production in the noncommunist world is expected to remain near the level obtained in 1976. The three large mines now under development in the Republic of South Africa will not start coming on stream until about 1979. There are no other developments in other parts of the world that could add significantly to gold output. The predicted price range for gold in 1977 should ensure continued operation of most of the world's producing gold mines at rates comparable to 1976.

Gold production in Canada in 1977 is expected to remain at about the same level as in 1976 but the long-term downward trend which began in 1961 is expected to continue in 1978. The improvement in the gold price in the latter part of 1976 and into 1977 will allow most of the lode gold mines to continue to operate in 1977. Gold recovered from base-metal ores is expected to remain near the 1976 level. The uncertainty that has existed as to the price level at which gold will stabilize has affected gold exploration in Canada. The gold price in the early part of 1977 appears to be showing some stability and should encourage an increase in exploration for gold properties.

Gypsum and Anhydrite

D.H. STONEHOUSE

Gypsum is a hydrous calcium sulphate ($CaSO_4 \cdot 2H_2O$) which, when calcined at temperatures ranging from 250° to 400°F, releases three quarters of its chemically combined water. The resulting hemihydrate of calcium sulphate, commonly referred to as plaster of paris, when mixed with water, can be moulded, shaped or spread and subsequently dried, or set, to form a hard plaster product. Gypsum is the main mineral constituent in gypsum wallboard, lath and tile. Anhydrite, the anhydrous calcium sulphate ($CaSO_4$), is commonly associated geologically with gypsum.

Crude gypsum is crushed, pulverized and calcined to form stucco, which is mixed with water and aggregate (sand, vermiculite or expanded perlite) and applied over wood, metal or gypsum lath to form interior wall finishes. Gypsum board, lath and sheathing are formed by introducing a slurry of stucco, water, foam, pulp and starch between two unwinding rolls of absorbent paper, which results in a continuous "sandwich" of wet board. As the stucco hardens, the board is cut to predetermined lengths, dried, bundled and stacked for shipment.

Keene's cement is made by converting crushed gypsum to insoluble anhydrite by calcining at temperatures as high as 1300°F, usually in rotary kilns. The ground calcine, mixed with a set accelerator, produces a harder and stronger plaster product than ordinary gypsum plaster.

Crude gypsum is also used in the manufacture of portland cement where it acts as a retarder to control set. It is used as a filler in paint and paper manufacture, as a substitute for saltcake in glass manufacture and as a soil conditioner.

Technological developments have enabled the economic utilization of phosphogypsum, a calcium sulphate byproduct of phosphate fertilizer manufacture, in some European countries and in Japan. Great quantities of phosphogypsum are accumulating in both the United States and Canada in regions where disposal costs will eventually encourage its use in gypsum products. The use of lime or limestone to desulphurize stack gases from utility or industrial plants burning high-sulphur fuel will also result in production of large amounts of waste gypsum sludge, which in itself will present disposal problems if profitable uses are not developed.

Production of gypsum in Canada is closely related to activity in the building construction industry, particularly in the residential building sector, in both Canada and the eastern United States. Between 70 and 75 per cent of Canadian gypsum production normally has been exported to the United States. During the recent period of economic recession in the United States exports were greatly reduced, to the lowest level since 1967. Canadian consumption has remained reasonably steady during the past four years at approximately 2 million tonnes.* Most of the gypsum for export is quarried in Nova Scotia and Newfoundland by Canadian subsidiaries of United States gypsum products manufacturers. Although most of the output from other provinces is used regionally, nearly all the Nova Scotia production is exported in large "in-company" shipments to the eastern United States.

Total construction in Canada in 1976 is estimated to have reached a value of over $32 billion, 60 per cent of which is credited to the building construction sector. Traditionally, one half of building construction expenditures are in the residential category where, in 1976, housing starts were increased by 18 per cent to 273 203 units. Gypsum production was down very slightly to 5 663 000 tonnes in 1976; wallboard, lath and sheathing production increased by 12 per cent.

Canadian industry and developments

Atlantic provinces. During 1976 five companies produced crude gypsum in Nova Scotia, two in New Brunswick and one in Newfoundland. Regional consumption of raw gypsum was small compared with the quantity exported to the United States from the Atlantic provinces. Three cement manufacturing plants, two

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, gypsum production and trade, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Crude gypsum				
Nova Scotia	3 895 387	12 806 185	3 874 000	13 804 000
British Columbia	474 390	1 751 799	535 000	3 628 000
Ontario	630 600	2 936 056	571 000	2 658 000
Newfoundland	582 857	2 314 562	558 000	2 436 000
Manitoba	83 456	286 273	83 000	203 000
New Brunswick	52 761	208 918	42 000	177 000
Total	5 719 451	20 303 793	5 663 000	22 906 000
Imports				
Crude gypsum				
Mexico	39 099	448 000	47 788	592 000
United States	16 179	219 000	6 958	184 000
United Kingdom	50	4 000	—	—
West Germany	10	1000	—	—
Total	55 338	672 000	54 746	776 000
Plaster of paris and wall plaster				
United States	19 235	1 851 000	25 226	2 234 000
United Kingdom	445	24 000	387	44 000
Italy	18	2 000	—	—
West Germany	7	. . .	—	—
Total	19 705	1 877 000	25 613	2 278 000
Gypsum lath, wallboard and basic products	(m^2)		(m^2)	
United States	10 202 035	4 818 000	23 940 279	11 718 000
United Kingdom	77	. . .	—	—
Total	10 202 112	4 818 000	23 940 279	11 718 000
Total imports gypsum and gypsum products		7 367 000		14 772 000
Exports				
Crude gypsum	(tonnes)		(tonnes)	
United States	3 676 275	11 340 000	3 798 243	13 100 000
Bahamas	15 401	41 000	—	—
Total	3 691 676	11 381 000	3 798 243	13 100 000

Source: Statistics Canada.
[p] Preliminary; — Nil; . . . Less than $1,000.

gypsum wallboard manufacturing plants and one plant producing plaster of paris, together used only about 100 000 tonnes. Crude gypsum from Nova Scotia is used by Quebec wallboard plants and by Quebec and Ontario cement producers, each supplying regional construction industries.

Fundy Gypsum Company Limited, a subsidiary of United States Gypsum Company, Chicago, mines gypsum by open-pit methods at Wentworth and at Miller Creek near Windsor, Nova Scotia, for export to the United States. Crushed and beneficiated crude gypsum is shipped to company-owned processing plants through the port of Hantsport, Nova Scotia.

National Gypsum (Canada) Ltd. produces gypsum from a quarry near Milford, Nova Scotia, and exports most of it through the port of Halifax to east coast United States plants operated by the parent company, National Gypsum Company of Buffalo, New York. Unit-trains of 40 cars each are used to haul gypsum from the quarry site 30 miles to Dartmouth. Company-owned, self-unloading ore carriers of up to 30 000 tonnes capacity are loaded at rates of up to 4500 tonnes an hour through facilities on Bedford Basin. Shipments by water are made to Quebec for use in the manufacture of gypsum products and cement, and by truck to Brookfield, Nova Scotia for use in cement manufacture.

Georgia-Pacific Corporation, Bestwall Gypsum Division, mines gypsum from a quarry near River Denys, Inverness County, Nova Scotia. Crushed rock is transferred by rail to open storage at Point Tupper, 20 miles from the quarry, and loaded on chartered vessels through a conveyor and reclaim tunnel system. Shipments are exported mainly to the Georgia-Pacific plant at Wilmington, Delaware.

Little Narrows Gypsum Company Limited, another subsidiary of United States Gypsum Company, produces gypsum from a quarry at Little Narrows, Victoria County, Nova Scotia, for shipments to the United States, Quebec and Ontario, through company ship-loading facilities near the plant site.

Domtar Construction Materials Ltd. operates a calcining plant at Windsor, Nova Scotia, for the production of plaster of paris. Gypsum for the plant is supplied from a quarry at MacKay Settlement, under contract with D. MacDonald.

Many other gypsum occurrences are known in the central and northern mainland of Nova Scotia and on Cape Breton Island.

Gypsum is mined at Flat Bay Station, Newfoundland, 60 miles southwest of Corner Brook, by Flintkote Holdings Limited, mostly for export to company plants in the United States. Raw gypsum is supplied to the Corner Brook plant of Atlantic Gypsum Limited for the manufacture of gypsum wallboard products and plaster of paris, and to the cement plant operated by North Star Cement Limited, also at Corner Brook. Exports are made through the port of St. George's from an open stockpile supplied by an aerial cable tramway carrying rock from Flat Bay, six miles from the shipping site. Other gypsum occurrences are known in the southwestern lowlands, west of the Long Range Mountains.

In New Brunswick, two companies quarry gypsum. Canadian Gypsum Company, Limited, a subsidiary of United States Gypsum Company, produces gypsum for use in the manufacture of plaster and wallboard in the company-owned plant at Hillsborough. Canada Cement Lafarge Ltd. obtains gypsum from the Havelock area, west of Moncton, for use in the manufacture of portland cement at Havelock.

Other gypsum occurrences in the southeastern counties of New Brunswick have been recorded. Many gypsum outcrops occur on the Magdalen Islands in Quebec.

Ontario. Two underground gypsum mines are operated in southwestern Ontario to produce raw material for three gypsum products plants and a number of cement manufacturing plants. Domtar Construction Materials Ltd. mines gypsum at Caledonia, near Hamilton, from an 8-foot seam 75 feet below the surface. Crude gypsum is shipped to other consumers as well as being supplied to the company's wallboard plant at the mine site, where a full range of gypsum building products is manufactured. Domtar plans to increase its wallboard capacity at Caledonia by 1978.

At Hagersville, southwest of Caledonia, Canadian Gypsum Company, Limited, a subsidiary of United States Gypsum Company, Chicago, produces crude gypsum by room-and-pillar mining methods from a 4-foot seam, reached through a 95-foot vertical shaft. Increased production from the mine is planned for 1978 to supply the requirements of the company's wallboard plant, at which a capacity expansion is now underway.

Westroc Industries Limited, Clarkson, has announced its intention to develop a new gypsum mine at Drumbo, in the township of Blandford-Blenheim, Oxford County. This will provide a captive source of crude gypsum for the company's wallboard plant at Mississauga which currently is supplied from Domtar's Caledonia mine. A 12-foot-diameter shaft to a depth of 400 feet will be started early in 1977 and the $5 million program is scheduled for completion in 1978. Reserves are sufficient to satisfy the company's needs and to supply other growing industrial and agricultural markets for 30 years. A current expansion program at the Mississauga plant will provide 30 per cent more capacity and is scheduled for completion in 1978 as well.

Gypsum has been proven at depths down to 200 feet in other parts of southwestern Ontario and under 10 to 30 feet of overburden in the Moose River area south of James Bay.

Western provinces. Crude gypsum was produced from two surface operations: one in Manitoba, one in British Columbia, providing raw material for ten wall-

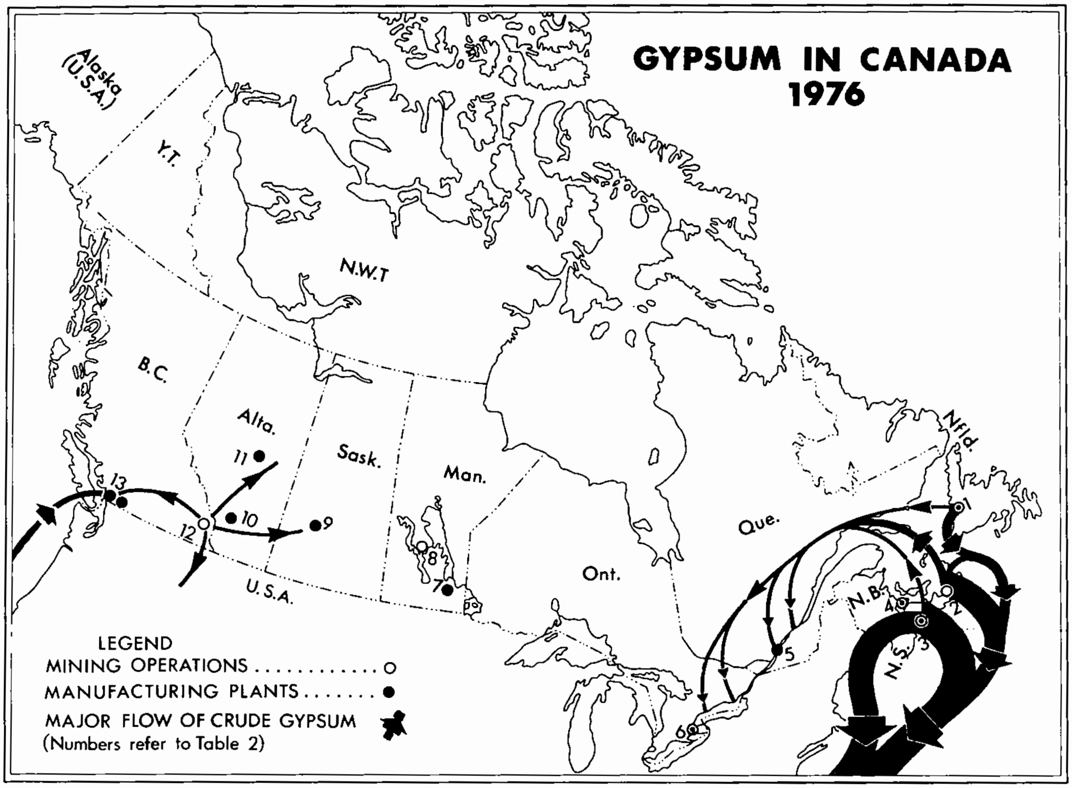


Table 2. Canada, summary of gypsum and gypsum products operation, 1976

Company	Location	Remarks
	(numbers refer to numbers on map)	
Newfoundland		
1. Flintkote Holdings Limited	Flat Bay	Open-pit mining of gypsum
Atlantic Gypsum Limited	Corner Brook	Gypsum products manufacture
Nova Scotia		
2. Little Narrows Gypsum Company Limited	Little Narrows	Open-pit mining of gypsum and anhydrite
Georgia-Pacific Corporation Bestwall Gypsum Division	River Denys	Open-pit mining of gypsum
3. Fundy Gypsum Company Limited	Wentworth and Miller Creek	Open-pit mining of gypsum and anhydrite
National Gypsum (Canada) Ltd.	Milford	Open-pit mining of gypsum
Domtar Construction Materials Ltd.	MacKay Settlement	Open-pit mining of gypsum
	Windsor	Gypsum plaster manufacture

Table 2. (concl'd)

Company	Location	Remarks
	(numbers refer to numbers on map)	
New Brunswick		
4. Canadian Gypsum Company, Limited	Hillsborough	Open-pit mining of gypsum and gypsum products manufacture
Canada Cement Lafarge Ltd.	Havelock	Open-pit mining of gypsum used in cement manufacture
Quebec		
5. Canadian Gypsum Company, Limited	Montreal	Gypsum products manufacture
Canadian Gypsum Company, Limited	St-Jérôme	Gypsum products manufacture
Domtar Construction Materials Ltd.	Montreal	Gypsum products manufacture
Westroc Industries Limited	Ste-Cathérine d'Alexandrie	Gypsum products manufacture
Ontario		
6. Canadian Gypsum Company, Limited	Hagersville	Underground mining of gypsum and gypsum products manufacture
Domtar Construction Materials Ltd.	Caledonia	Underground mining of gypsum and gypsum products manufacture
Westroc Industries Limited	Clarkson	Gypsum products manufacture
	Drumbo	Underground mine development
Manitoba		
7. Domtar Construction Materials Ltd.	Winnipeg	Gypsum products manufacture
Westroc Industries Limited	Winnipeg	Gypsum products manufacture
8. Domtar Construction Materials Ltd.	Gypsumville	Open-pit mining of gypsum
Saskatchewan		
9. BACM Industries Limited	Saskatoon	Gypsum products manufacture
Alberta		
10. Domtar Construction Materials Ltd.	Calgary	Gypsum products manufacture
Westroc Industries Limited	Calgary	Gypsum products manufacture
11. BACM Industries Limited	Edmonton	Gypsum products manufacture
British Columbia		
12. Western Gypsum Ltd.	Windermere	Open-pit mining of gypsum
13. Westroc Industries Limited	Vancouver	Gypsum products manufacture
Domtar Construction Materials Ltd.	Vancouver	Gypsum products manufacture
BACM Industries Limited	Vancouver	Gypsum products manufacture

board manufacturing plants. Imports, mainly from Mexico, totalled 54 746 tonnes in 1976 and were used principally in the Vancouver region.

Domtar Construction Materials Ltd. obtains crude gypsum from its quarry at Gypsumville, 150 miles northwest of Winnipeg, Manitoba. The company's gypsum products plant at Winnipeg uses crude from this source.

Westroc Industries Limited mined gypsum from a deposit 140 feet beneath the surface near Silver Plains, 30 miles south of Winnipeg, until mid-1975 when an inflow of artesian water from below the orebody forced the closure of the mine. Crushed and screened gypsum had been supplied to company-operated gypsum products plants in Winnipeg and Saskatoon and to cement manufacturers in Winnipeg, Regina and Saskatoon. This demand is now met with crude gypsum from Gypsumville and Windermere, B.C.

Western Gypsum Ltd., a subsidiary of Westroc Industries Limited, operates an open-pit mine near Windermere in the southeastern part of British Columbia, supplying raw gypsum to its products plant at Calgary and Vancouver, to the Calgary and Vancouver plants of Domtar Construction Materials Ltd., to the Edmonton plant of BACM Industries Limited, to cement manufacturers in the Vancouver area, Kamloops, Exshaw and Edmonton, and to markets formerly supplied from the company's mine at Silver Plains, Manitoba.

Gypsum occurs in Wood Buffalo National Park, in Jasper National Park, along the Peace River between Peace Point and Little Rapids, and north of Fort Fitzgerald in Alberta; on Featherstonhaugh Creek, near Mayook, Canal Flats, Loos, and Falkland in British Columbia; on the shores of Great Slave Lake, the Mackenzie, Great Bear and Slave rivers in the Northwest Territories; and on several Arctic islands.

Markets, trade and outlook

Because gypsum is a relatively low-cost, high-bulk mineral commodity it is generally produced from those deposits situated as conveniently as possible to areas in which markets for gypsum products exist. Exceptions occur if deposits of unusually high quality are available, even at a somewhat greater distance from markets, if comparatively easy and inexpensive mining methods are applicable, or if low-cost, high-bulk shipping facilities are accessible. Nova Scotia and Newfoundland deposits meet all three of these criteria and have been operated for many years by and for United States-based companies in preference to United States deposits.

Exports of crude gypsum are mainly to the eastern United States where the demand for gypsum products bears close relation to activity in the construction industry. During the recent period of economic recession, the construction industry in both the United States and Canada was depressed. Although the Canadian industry rallied in early- to mid-1975, the

Table 3. World production of gypsum, 1975-76

	1975	1976[e]
	(thousand tonnes)	
United States	8 846	10 433
France	5 813	6 350
Canada	5 719	5 663
Spain	4 173	4 627
United Kingdom	3 629	3 992
Other Free World	19 265	21 137
Communist countries	7 307	7 983
World Total	54 752	60 185

Sources: United States Bureau of Mines Commodity Data Summaries, January 1977; and for Canada, Statistics Canada.
[e] Estimated.

Table 4. Canada, gypsum production, trade and consumption, 1965, 1970, 1974-76

	Production[1]	Imports[2]	Exports[2]	Apparent Consumption[3]
	(tonnes)			
1965	5 720 370	68 432	4 306 068	1 482 734
1970	5 732 068	35 271	4 402 843	1 364 496
1974	7 225 203	56 251	5 212 430	2 069 024
1975	5 719 451	55 338	3 691 676	2 083 113
1976[p]	5 663 000	54 746	3 798 243	1 919 503

Source: Statistics Canada.
[1] Producers' shipments, crude gypsum. [2] Includes crude and ground, but not calcined. [3] Production, plus imports, minus exports.
[p] Preliminary.

Table 5. Canada, production of gypsum products, 1975-76

Item	1975	1976
	(m^2)	
Wallboard	125 391 670	141 268 952
Lath	7 187 170	7 265 425
Sheathing	4 353 403	4 885 696
	(tonnes)	
Plaster	80 739	57 557

Source: Statistics Canada.

United States industry remained depressed until near the end of the year, at which time an upturn was evident. Reduced construction activity resulted in reduced demand for gypsum products, which in turn resulted in gypsum exports from eastern Canada being less in 1975 than at any time since 1967. Gypsum wallboard production in the United States during 1976 showed a surprising increase which can be accounted for only in part by the general upturn in construction. Of significant importance is the development of a market for wallboard in non-residential construction where its fire-proofing and sound-insulating qualities are plus factors.

Crude gypsum, mainly from the Newfoundland port of St. George's and from Halifax and Little Narrows in Nova Scotia, is shipped to the Montreal and Toronto areas for use in gypsum products manufacture and portland cement production. Since the closure of the Westroc Industries Limited mine at Silver Plains, Manitoba, gypsum from Windermere, B.C. is rail-hauled abnormally long distances to supply the needs of cement producers and the gypsum products industry in the prairie provinces. Raw gypsum is imported on the west coast from Mexico, mainly for cement manufacture. Minor amounts of crude gypsum have been shipped to the mid-United States for agricultural use, and quantities have been exported to the northwestern United States from British Columbia, mainly for use by cement manufacturers.

Gypsum products are not shipped great distances because freight and handling costs represent a major part of the price to the consumer for items that are relatively low-priced and readily available at many locations. Although gypsum products are usually manufactured close to the consumer, with modern containerized shipments becoming more popular and with the trend to trade off economic and environmental factors, the establishment of wallboard plants at the raw material source could become attractive.

Construction expenditures in both Canada and the United States are expected to increase. Construction of homes, apartments, schools and offices will continue and the need for gypsum-based building products will rise steadily. Although new construction materials are being introduced, gypsum wallboard will remain popular because of its low price, ease of installation and well-recognized insulating and fire retarding properties. The present structure of the gypsum industry in Canada is unlikely to change greatly in the near future. Building materials plants either have sufficient capacities to meet the short-term, regional demand for products or are implementing expansion programs to provide greater capacity. Exploitable deposits in the Prairie region and in Ontario will continue to attract attention.

A charge of price fixing was laid September 30, 1976 against four Canadian gypsum wallboard manufacturers: Domtar Construction Materials Ltd., Westroc Industries Limited, BACM Industries Limited, and Truroc Gypsum Products Ltd., following an investigation by the Department of Consumer and Corporate Affairs. The charge is based on activities in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario and Quebec over the period from December 1, 1968 to March 31, 1974. The companies are to appear for preliminary hearing in Toronto in April 1977. The specific charge is "conspiring to lessen competition in the production, manufacture, sale or supply of gypsum wallboard".

Canadian Standards Association standards A 82.20 and A 82.35 relate to gypsum and gypsum products.

World review

Gypsum occurs in abundance throughout the world but, because its use is dependent on the building construction industry, developments are generally limited to the industrialized countries. Reserves are extremely large and are conservatively estimated at over 2 billion tonnes. Accumulations of byproduct chemical gypsum (including phosphogypsum) will undoubtedly become attractive as sources of calcium sulphate for both cement and wallboard manufacture in North America, as indeed they have in Europe and Japan. Increasing disposal costs will motivate the use of these products. Stringent regulations regarding the removal of SO_2 from stack gases are not too far in the future and one of the possible products of such emission controls, if the world sulphur system does not require either sulphuric acid or elemental sulphur, would be calcium sulphate. The technology exists to economically utilize chemical gypsum. For example, in Japan in 1976, where total gypsum production was 5 563 000 tonnes, only 150 000 tonnes was natural gypsum, produced from one operating mine, the rest was phosphogypsum (3 228 000 tonnes) and other chemical gypsum (2 185 000 tonnes). Over 65 per cent was used for wallboard and plaster manufacture and about 30 per cent was used in portland cement manufacture.

The United States is the world's largest single producer of natural gypsum and, together with Canada, brings North American production to about 27 per cent of world output. European production is about 46 per cent of the world total, with France being the largest producer. Asian producers account for about 9 per cent of the world total; the four major producers being Iran, India, the People's Republic of China and Japan. Mexico, Central America, South America, Africa and Oceania each produce significant amounts, with Mexico contributing by far the greatest tonnage of any country in this group.

Anhydrite

Production and trade statistics for anhydrite are included with gypsum statistics. Anhydrite is produced by Fundy Gypsum Company Limited at Wentworth, Nova Scotia, and by Little Narrows Gypsum Company Limited at Little Narrows, Nova Scotia. According to the Nova Scotia Annual Report on Mines, production of anhydrite in 1976 was 207 310 tonnes. Most of this was shipped to the United States for use in portland cement manufacture and as a peanut crop fertilizer. Cement plants in Quebec and Ontario also used some Nova Scotia anhydrite.

Table 6. Canada, house construction, by province

	Starts			Completions			Under Construction		
	1975	1976	% Diff.	1975	1976	% Diff.	1975	1976	% Diff.
Newfoundland	5 342	5 709	+7	4 831	5 850	+21	5 107	4 537	−11
Prince Edward Island	847	842	−1	1 130	989	−12	314	183	−42
Nova Scotia	6 366	7 470	+17	6 249	7 364	+18	7 301	7 307	+0
New Brunswick	6 983	6 772	−3	5 804	7 137	+23	4 463	3 873	−13
Total (Atlantic Provinces)	19 538	20 793	+6	18 014	21 340	+18	17 185	15 900	−8
Quebec	54 741	68 748	+26	51 540	54 301	+5	31 805	43 600	+37
Ontario	79 968	84 682	+6	81 865	80 302	−2	75 690	78 359	+4
Manitoba	7 845	9 339	+19	8 760	8 492	−3	4 917	5 820	+18
Saskatchewan	10 505	13 143	+25	7 705	11 046	+43	7 728	9 319	+21
Alberta	24 707	38 771	+57	17 550	25 858	+47	16 909	29 411	+74
Total (Prairie Provinces)	43 057	61 253	+42	34 015	45 396	+33	29 554	44 550	+51
British Columbia	34 152	37 727	+10	31 530	34 910	+11	22 365	21 877	−2
Total Canada	231 456	273 203	+18	216 964	236 249	+9	176 599	204 286	+16

Source: Statistics Canada.

Tariffs

Canada

Item No.		British Preferential Tariff	Most Favoured Nation	General	General Preferential
29200-1	Gypsum, crude	free	free	free	free
29300-1	Plaster of paris, or gypsum calcined, and prepared wall plaster, the weight of the package to be included in the weight for duty per 100 pounds	free	6¢	12½¢	free
29400-1	Gypsum, ground not calcined	free	free	15%	free
28410-1	Gypsum tile	15%	15%	25%	10%

United States

512.21	Gypsum, crude	free
512.24	Gypsum, ground calcined	59c per long ton
245.70	Gypsum or plastic building boards and lath	6%

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), T.C. Publication 749.

Indium

D.H. BROWN

Indium occurs as a minor constituent of certain ores of zinc, lead, tin, tungsten and iron. It is commonly associated with sphalerite, the most abundant zinc mineral. Indium becomes concentrated in zinc residues and smelter slags derived from zinc and lead smelting operations. It is recovered at only a few of the world's zinc and lead smelters.

Canadian output of indium in 1976 was 6 128.7 kilograms compared with 6 967.2 kilograms in 1975. Cominco Ltd. is the only Canadian producer of indium and one of the world's largest producers of the metal.

Other major producers of indium are located in the United States, Japan, West Germany, Australia, Peru and Belgium. Statistical data on output and consumption of indium in these countries are not generally available, although the United States Bureau of Mines estimates 1976 world production at 48 210.4 kilograms. During the year indium supply did not keep pace with demand because, as reported in the August 20, 1976 edition of the Metal Bulletin published in London, England, ASARCO Incorporated and Cominco Ltd. registered a decline in production due to a lower indium content of zinc ores being processed, and supply from the U.S.S.R. was curtailed.

Production

Indium was first recovered at Trail, British Columbia in 1941, but the presence of indium in the lead-zinc-silver ores of Cominco's Sullivan mine at Kimberley, British Columbia, had been known for many years. In 1942, 13.6 kilograms were produced by laboratory methods. After a decade of intensive research and development production began in 1952 on a commercial scale. At present the potential annual production at Trail is 31 103.5 kilograms.

Indium enters the Trail metallurgical plants in the zinc concentrates. In the electrolytic zinc process indium remains in the zinc calcine during roasting and in the insoluble residue during leaching. The residue is then delivered to the lead smelter for recovery of contained lead and residual zinc. In the lead blast furnaces the indium enters lead bullion and blast furnace slag in about equal proportions. From the slag, it is recovered along with zinc and lead during slag-fuming. The fume is leached for recovery of zinc, and indium again remains in the residue, which is retreated in the lead smelter. From the lead bullion, indium is removed in bullion dross. The dross is retreated for recovery of copper matte and lead and, in this process, a slag is recovered which contains lead and tin, together with 2.5 to 3.0 per cent indium.

The dross retreatment slag is reduced electrothermally to produce a bullion containing lead, tin, indium and antimony, which is treated electrolytically to yield a high (20 to 25 per cent) indium anode slime. The anode slime is then treated chemically to give a crude (99 per cent) indium metal, which is refined electrolytically to produce a standard grade (99.97 per cent) or a high-purity grade (approximately 99.999 to 99.9999 per cent) indium. The metal is cast in ingots varying in size from 0.3 kilograms to 10 kilograms. Also produced are various alloys and chemical compounds of indium, such as indium antimonide; and a variety of fabricated forms such as discs, wire, ribbon, foil and sheet, powder, and spherical pellets.

Properties and uses

Indium is a silver-white metal that resembles tin in its physical and chemical properties. Its chief characteristics are extreme softness, low melting point and high boiling point. The metal has a melting point of 156°C; boiling point of 2 000°C; and atomic weight of 114.8. Its specific gravity at 20°C is 7.31 which is about the same as that of iron.

Indium forms alloys with precious metals and many of the base metals, improving their performance in certain special applications. Its first major use, and still an important outlet, was in high-speed silver-lead bearings in which the addition of indium increases the strength and corrosion resistance of the surfaces of the bearings. Bearings of this type are used in aircraft piston engines, diesel engines and several types of automobile engines. The standard grade of indium is used in this application.

Indium is used in low-melting-point alloys containing bismuth, lead, tin and cadmium; e.g., a bismuth-tin-cadmium-lead-indium alloy containing 19.1 per cent indium used as a heat fuse melts at 47°C. Indium is used in glass-sealing alloys containing about equal amounts of tin and indium, in certain solder alloys in which resistance to alkaline corrosion is required, and in gold dental alloys.

Indium is one of several metals that find application in various semiconductor devices. In these, high-purity indium, alloyed in the form of discs or spheres into each side of a germanium wafer, modifies the properties of the germanium. Indium is especially suitable for this purpose because it alloys readily with germanium at low temperatures and, being a soft metal, does not cause strains on contracting after alloying.

Discovered in 1863, but in commercial use only since 1927 when it was first used as a nontarnish coating on silverware, indium and its compounds are relatively new materials whose potential applications are still being explored. Uses have been found in manufacturing electrical contacts, resistors, thermistors, photoconductors, small lightweight batteries and infrared detectors. Indium can be used as an indicator in atomic reactors because artificial radioactivity is easily induced in the metal by neutrons of low energy (about 1.5 electron-volt). Indium foil was used as a neutron indicator in the uranium-graphite piles of the first atomic bomb project. Silver-cadmium-indium alloys are now used in reactor control rods. Indium compounds added to lubricants have a beneficial anti-corrosive effect. Indium is plated as a coating on screws in electrical sockets associated with aluminum wiring and it also has possible applications in decorative plating of jewellry and tableware.

The United States Bureau of Mines estimated that in 1976 the uses of the metal were distributed as follows: solder, alloys and coatings, 40 per cent; instruments, 30 per cent; electronic components, 10 per cent and other uses, 20 per cent. Compared to 1975, usage in solder, alloys and coatings increased by 10 per cent while electronic components and other uses declined by 8 per cent and 2 per cent respectively.

Foreign Trade

Detailed statistics on foreign trade are not available for indium. United States imports of the metal in 1976 were estimated by the U.S. Bureau of Mines at 8 864.5 kilograms compared with 3 234.8 kilograms in 1975, 15 334 kilograms in 1974, and 25 224.9 kilograms in 1973. The sources of the imports for the period 1972-75 were: Canada, 36 per cent; U.S.S.R., 14 per cent; Peru, 15 per cent; United Kingdom, 13 per cent and others, 22 per cent.

Prices

The price of indium as quoted by *Metals Week* in the United States at the beginning of 1976 was $6.00 an ounce* delivered for metal having a minimum purity of 99.7 per cent. This quotation represents the announced selling prices of ASARCO Incorporated and the Indium Corporation of America, the sole domestic metal producers. Price changes during the year in response to increasing supply shortages were as follows:

Effective dates, 1976	Price per oz.	Company
April 1	$7.00	ASARCO Inc.
	$7.25	Indium Corp.
April 26	$7.90	Indium Corp.
June 22	$8.75	Indium Corp.
June 29	$8.00	ASARCO Inc.
August 6	$9.25	Indium Corp.
August 23	$9.00	ASARCO Inc.
	$9.95	Indium Corp.
September 20	$10.25	Indium Corp.
October 7	$10.00	ASARCO Inc.

Year-end quotations continued to reflect the split price for indium in the United States at $10.00 to $10.25 an ounce.

*The term ounce or its abbreviation oz. refers to a troy ounce, equivalent to 31.103 5 grams.

Tariffs

Canada — not specifically enumerated in Canadian tariffs.

United States

Item No.		Rate of Duty January 1, 1977
		%
628.45	Metal, unwrought, waste and scrap[1]	5
628.50	Metal, wrought	9

Source: Tariff Schedules of the United States Annotated (1976) T.C. Publication 749.
[1]Duty on waste and scrap suspended until June 30, 1978.

Iron Ore

MICHEL A. BOUCHER

Events of importance in the Canadian iron ore industry during 1976 include: higher gross incomes for the iron ore mining companies due to a combination of price and production increases, increased shipments and exports, and the closure of Texada Mines Ltd. in British Columbia.

The Canadian iron ore industry performed very well during the year as production shipments increased from 44 892 530 tonnes* valued at $918 064 741 in 1975 to 56 902 000 tonnes valued at $1 241 263 000 in 1976. The increase in production was due mainly to improvements in the operations of Wabush Mines, Iron Ore Company of Canada, and to new production from the Mount Wright operation in Quebec, owned by Quebec Cartier Mining Company, a subsidiary of United States Steel Corporation. Exports increased from 36 033 842 tonnes to 44 684 868 tonnes in 1976. Exports are likely to increase considerably in the next two years as the Mount Wright development reaches full production of 18 to 20 million tonnes a year in 1978. All production at Mount Wright will be exported.

Imports decreased from 4 844 416 tonnes in 1975 to 3 020 130 tonnes in 1976. This was due to increased production from Wabush Mines in which The Steel Company of Canada, Limited (Stelco) and Dominion Foundries and Steel, Limited (Dofasco) have some interests. Imports, however, are expected to increase during the next three years as new taconite deposits in the United States, in which Stelco, Dofasco and The Algoma Steel Corporation, Limited (Algoma) have taken equity participation, are fully developed and production reaches capacity.

In 1977 Dofasco will receive a total of about 0.6 million tonnes of pellets a year from its terms of investment in the Eveleth mine in Minnesota. In 1979 Stelco will receive a total of some 3.5 million tonnes of pellets a year from its equity participation in the Erie, Eveleth and Hibbing mines in Minnesota and the Tilden mine in Michigan, while Algoma will receive some 3.1 million tonnes of pellets a year from its investment in the Tilden mine. These imports will represent a very important portion of the total iron ore requirements of the Canadian steel companies. The three companies decided to invest in the United States rather than in Canada for several reasons. First is the proximity of the United States iron ore mines to the Ontario-based steel companies, which reduces transportation costs; second, is that the investment was made in areas with already-established infrastructures; and third, the ability to contract for relatively small tonnages in participation with other iron ore mining companies. Consequently, much less capital investment was required. Imports from Brazil are likely to decline as production of concentrates from the new pellet plant of Sidbec-Normines Inc. at Port Cartier increases to 6.0 million tonnes a year in 1978.

Iron ore consumption in 1976 was 13.7 million tonnes compared with 12.7 million tonnes in 1975.

Canadian developments

No new projects were started in the iron ore industry in Canada during 1976 and most activity, which consisted of expansion of existing facilities or production improvements, was concentrated in the Quebec and Quebec-Labrador regions.

Quebec and Quebec-Labrador

Major investments in the iron ore industry are likely to be concentrated in the Quebec-Labrador region for the next 10 years as most of the large iron ore deposits amenable to open-pit mining are concentrated in the south part of the Labrador geosyncline where infrastructures already exist. Several large deposits remain to be developed in this region, including Mount Reed, Quebec Cobalt, Julian Lake, and O'Keefe Star. There are also several similar deposits located on the north part of the Labrador geosyncline along the west side of Ungava Bay.

Mount Wright. Apart from higher-than-expected escalation of costs, the Mount Wright project, owned by Quebec Cartier Mining, a subsidiary of U.S. Steel, is being developed as expected. Concentrate production

*The term "tonne" refers to the metric ton of 2 204. 62 pounds.

in 1976 was 8 million tonnes and, when completed in 1978, production should be between 18 and 20 million tonnes a year. The concentrates are reported to be very good for sintering. In 1978 it is expected that some 12 million tonnes a year will be exported to western Europe, mainly to the United Kingdom and West Germany. The U.S. Steel Corp. will take another 5 million tonnes a year and Japan one million tonnes. The Mount Wright project represents an investment of almost $700 million by U.S. Steel.

Fire Lake. By mid-1977 reserves at Lac Jeannine will be exhausted. Gradually production is being replaced by that of Fire Lake, a mine located some 64 km

Table 1. Canada, iron ore production and trade, 1975-76

	1975		1976^p	
	(tonnes)[1]	($)	(tonnes)[1]	($)
Production (mine shipments)				
Newfoundland	22 585 446	468,600,400	27 970 000	643,455,000
Quebec	11 501 425	215,155,294	17 754 000	324,607,000
Ontario	9 503 813	219,024,019	10 369 000	264,111,000
British Columbia	1 301 846	15,285,028	809 000	9,090,000
Total[2]	44 892 530	918,064,741	56 902 000	1,241,263,000
Imports				
United States	3 979 780	97,614,000	2 822 560	75,802,000
Brazil	689 734	19,200,000	144 170	3,961,000
Sweden	128 019	4,733,000	38 281	1,319,000
South Africa	—	—	15 116	432,000
Mexico	—	—	3	. . .
Norway	33 116	1,038,000	—	—
Morocco	13 639	450,000	—	—
Liberia	128	3,000	—	—
Total	4 844 416	123,038,000	3 020 130	81,514,000
Exports				
Iron ore, direct shipping				
United States	3 123 525	48,378,000	2 837 853	47,923,000
Italy	599 997	9,359,000	571 023	9,721,000
Japan	—	—	395 469	6,431,000
United Kingdom	580 786	7,270,000	336 396	5,037,000
Belgium-Luxembourg	111 786	1,717,000	225 853	3,844,000
Netherlands	—	—	32 615	353,000
Total	4 416 094	66,724,000	4 399 209	73,309,000
Iron ore concentrates				
United States	3 743 849	65,440,000	6 228 848	115,293,000
Netherlands	2 816 716	36,614,000	3 642 757	51,844,000
Japan	3 987 115	41,525,000	4 472 032	46,554,000
United Kingdom	2 448 285	36,540,000	2 912 381	40,667,000
West Germany	1 845 110	29,487,000	2 061 869	31,118,000
Italy	929 842	12,801,000	1 272 223	17,330,000
France	480 503	6,142,000	877 470	11,645,000
Spain	95 088	1,653,000	146 436	2,269,000
Finland	63 525	1,100,000	99 797	1,621,000
Austria	—	—	76 965	1,187,000
Portugal	70 420	1,845,000	51 088	1,125,000
Australia	31 141	569,000	29 239	686,000
Bahamas	7 773	136,000	—	—
Total	16 519 367	233,852,000	21 871 105	321,339,000

Table 1. (concl'd)

	1975		1976p	
	(tonnes)[1]	($)	(tonnes)[1]	($)
Iron ore agglomerated				
United States	11 961 052	304,082,000	15 238 406	434,400,000
Netherlands	935 565	24,760,000	1 243 876	35,957,000
Spain	555 359	14,823,000	590 407	16,993,000
Italy	625 315	15,825,000	304 032	8,924,000
West Germany	278 314	7,349,000	312 201	8,897,000
United Kingdom	52 175	1,213,000	265 686	7,706,000
Japan	226 436	5,841,000	220 510	6,268,000
Belgium-Luxembourg	—	—	44 636	1,318,000
Total	14 634 216	373,893,000	18 219 754	520,463,000
Iron ore not elsewhere specified				
United States	464 165	11,257,000	194 800	5,352,000
Total exports all classes				
United States	19 292 591	429,157,000	24 499 907	602,968,000
Netherlands	3 752 281	61,374,000	4 919 248	88,154,000
Japan	4 213 551	47,366,000	5 088 011	59,253,000
United Kingdom	3 081 246	45,023,000	3 514 463	53,410,000
West Germany	2 123 424	36,836,000	2 374 070	40,015,000
Italy	2 155 154	37,985,000	2 147 278	35,975,000
Spain	650 447	16,476,000	736 843	19,262,000
France	480 503	6,142,000	877 470	11,645,000
Belgium-Luxembourg	111 786	1,717,000	270 489	5,162,000
Finland	63 525	1,100,000	99 797	1,621,000
Austria	—	—	76 965	1,187,000
Portugal	70 420	1,845,000	51 088	1,125,000
Australia	31 141	569,000	29 239	686,000
Bahamas	7 773	136,000	—	—
Total	36 033 842	685,726,000	44 684 868	920,463,000
Consumption of iron ore at Canadian iron and steel plants	12 674 768	. .	13 694 489	. .

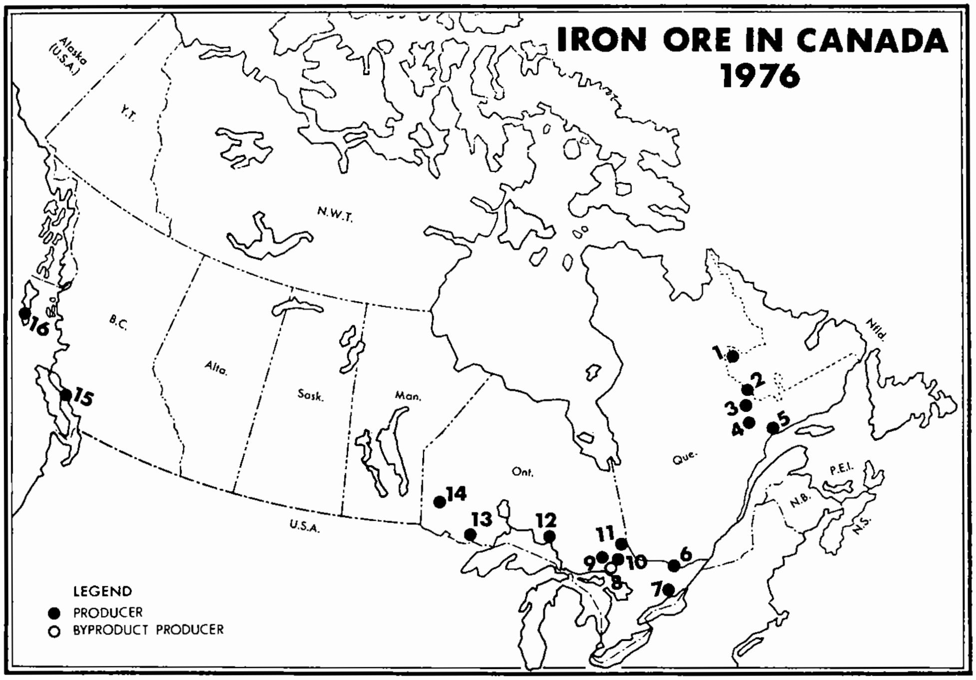
Source: Statistics Canada.
[1]Dry tonnes for production (shipments) by province; wet tonnes for imports and exports. [2]Total iron ore shipments include shipments of byproduct iron ore.
pPreliminary; — Nil; . . Not available.

northeast of Gagnon. The ore from Fire Lake is transported to Gagnon where it is concentrated. When the mine reaches full production in 1978 it will produce 6 million tonnes of concentrates a year. In 1976 it produced 1.5 million tonnes of concentrates. When construction of the new pellet plant at Port Cartier is completed in late 1977 the concentrates will be brought to the plant for further reduction in size. Half will be treated by a high-intensity magnetic separator in order to lower their silica content. The two concentrates will then be pelletized on two separate lines. One of the lines will produce 3 million tonnes a year of 68 per cent Fe with less than 2.5 per cent silica for use in direct reduction plants. The other line will produce 3 million tonnes a year of 66 per cent Fe with more than 6 per cent silica for blast furnace feed. The Fire Lake project represents an investment of $545 million and is being financed by Quebec Cartier Mining, Sidbec-Dosco Limited and British Steel Corporation. The distribution of production is in direct relation with the financial participation of the companies and will be as follows:

	Sidbec-Dosco	British Steel	QCM
		(millions of tonnes)	
Pellets (66% Fe)	Nil	2.5	0.5
Pellets (68% Fe)	3	Nil	Nil

The project is managed by QCM, but, in 1977, it will be managed by Sidbec-Normines, a newly formed company. Initially about half of the production of superconcentrates will be used by Sidbec at its Contrecoeur plant, with the remainder being sold. By 1985, however, it is expected that the whole production of superconcentrates will be consumed by Sidbec.

Sept-Iles. Iron Ore Company's new concentrator and pellet plant at Sept-Iles was completed in 1973. The plant treats a blend of 85 per cent blue ore (blue hematite) and 15 per cent yellow ore (limonite and goethite) from the Schefferville area. A new technology had to be developed to treat this type of ore and many problems had to be solved. Most design prob-



PRODUCERS

(numbers refer to numbers on map)

1. Iron Ore Company of Canada, Knob Lake Division (Schefferville)

2. Iron Ore Company of Canada, Carol Division, (Labrador City)

2. Scully Mine of Wabush Mines (Wabush)

3. Quebec Cartier Mining Company (Mount Wright)

4. Sidbec Normines Inc. (Gagnon, Fire Lake)

5. Iron Ore Company of Canada, Sept-Iles Division (Sept-Iles)

5. Pointe Noire Division of Wabush Mines (Pointe Noire)

6. Hilton Mines Ltd. (Shawville)

7. Marmoraton Mining Company, Division of Bethlehem Chile Iron Mines Company (Marmora)

9. National Steel Corporation of Canada, Limited (Capreol)

10. Sherman Mine of Dominion Foundries and Steel, Limited (Temagami)

11. Adams Mine of Dominion Foundries and Steel, Limited (Kirkland Lake)

12. Algoma Ore Division of The Algoma Steel Corporation, Limited (Wawa)

13. Caland Ore Company Limited (Atikokan) Steep Rock Iron Mines Limited (Atikokan)

14. The Griffith Mine (Bruce Lake)

15. Texada Mines Ltd. (Texada Is.)

16. Wesfrob Mines Limited (Moresby Is.)

BYPRODUCT PRODUCERS

8. Inco Limited (Copper Cliff)

lems are now reported solved and full production should be attained in 1978. The pellet plant is designed for an annual production of 6 million tonnes and in 1976 production reached 3.7 million tonnes. Some studies are presently being carried out to test the treatability of the red ore which is composed of very fine grained hematite. This ore is presently being sold as direct shipping without any treatment.

Feral Project. In 1974 James Bay Development Corporation (JBDC) took out options to acquire majority control of Albanel Minerals Limited, which held rights to the main deposits in the Lac Albanel area. The JBDC exercised its options in January 1976. Drilling was carried out during 1975 and 1976 and reported reserves now stand at over one billion tonnes of magnetite ore grading 31 per cent Fe. A prefeasibility study indicates that an annual production rate of 9 million tonnes of pellets a year would permit a reasonable rate of return on the capital invested. The Feral project would include, among other facilities, a concentrator at Lac Albanel and a pellet plant at Port Alfred on the Saguenay River. The concentrates would be transported either by rail or pipeline. Pellets containing 66 per cent Fe and 4 to 5 per cent SiO_2 would be suitable for blast furnace, and possibly for direct reduction by lowering the silica content. Production is expected to start in 1984. The concentrator and the pellet plant would represent a total investment of about $400 million (in 1975 dollars).

Ferchib Project. During the year Campbell Chibougamau Mines Ltd. retained the services of Marcona Corporation to prepare a preliminary market study for the production of pellets by Ferchib. Campbell Chibougamau has delineated some 300 million tonnes of magnetite ore and hopes to produce 4 million tonnes of pellets a year for use in direct reduction plants. The pellets would contain 66 per cent Fe, 2.5 per cent silica and 1.0 per cent titania.

Several problems remain to be solved for the Feral and Ferchib projects. They include high transportation costs, financing, and marketing of the products. In this respect, Canadian National and Canadian Pacific Railways are studying the possibility of using electric trains to transport the ore. Electrical energy would be supplied by the Quebec Hydro-Electric Commission (Hydro-Quebec) from the James Bay area.

Hilton Mine. Hilton Mines, Ltd. will cease operations at its iron ore mine near Shawville early in 1977 when its ore reserves are depleted. The Hilton mine started production in 1958 and at the end of 1976 it had produced a total of some 14.5 million tonnes of pellets. About half of its annual production of 0.9 million tonnes of pellets is shipped to Stelco, and the remainder is shipped to the United States. Currently, feed from the mine at Shawville is being supplemented experimentally by feed from a small former producer, the Hull mine, near Hull, Quebec. The closure will result in the loss of some 300 jobs.

Transportation. Large quantities of iron ore are being shipped annually from the Quebec-Labrador region to Sept-Iles and Port Cartier. Diesel oil is the only source of energy used by the train carriers. In the past two years fuel costs have increased considerably and it is believed these costs will continue to increase. For this reason both QCM and IOC have commissioned the CNR and the CPR to study the possibility of using hydroelectric energy rather than oil in the transportation of iron ore. Results of the studies will be known in about two years. Hydroelectric energy would be available from Churchill Falls, Labrador through Hydro-Quebec.

Ontario

Iron ore reserves in Ontario are much smaller than in the Quebec-Labrador region; the deposits are also smaller and widespread, requiring new infrastructures for their development.

The areas that attracted attention in the past two years were Lake St. Joseph, Geraldton-Nakina and Bending Lake. Because of their location, Algoma is the steel company in Canada most likely to show some interest in their development. In 1976, however, nothing was done on the Lake St. Joseph property and not much is expected to be done for the next couple of years due to escalation in construction costs, the less-than-expected growth in the steel industry in North America and recent investments by Algoma in the Tilden mine in the United States.

Geraldton-Nakina. Metallurgical work continued on the ore of the Geraldton property during the year but at a reduced rate.

Bending Lake. Jointly with Algoma, Steep Rock Iron Mines Limited is studying the possibility of developing the Bending Lake iron ore deposit, located 25 kilometres northwest of Atikokan. The ore at Bending Lake consists of magnetite grading 20 per cent Fe and the reserves are sufficient to sustain a mining operation for 20 years. The ore would be mined by open-pit methods, concentrated at Bending Lake and shipped by rail or pipeline to Atikokan for pelletizing at the existing operations. Because magnetite contains much less moisture than hematite-goethite presently mined by Steep Rock at Atikokan the pellet plant's capacity would increase from 1.4 million tonnes to 2.5 million tonnes.

Caland. Caland Ore Company Limited has indicated that it plans to terminate mining operations in 1979. At that time the property will return to its original owner, Steep Rock. Meanwhile, Caland is stockpiling material which in its operation is considered low-grade, containing 40 to 50 per cent Fe, for future possible use by Steep Rock.

In order to mine all the reserves of iron ore available large quantities of silt must be removed, and to do so the company makes use of a system developed by Marcona and known as the Marconaflo system. The

(text continued on page 259)

Table 2. Canada, iron ore producers, 1975 and 1976

Company and Property Location	Participating Companies	Material Mined and/or Treated 1976	Product Shipped 1976	Shipments 1975	Shipments 1976
		(% Fe natural)	(% Fe dry/wet)	(000 tonnes)	
Adams Mine: Boston Twp., near Kirkland Lake, Ont.	Dominion Foundries and Steel, Ltd.; managed by Cliffs of Canada Limited, a wholly-owned subsidiary of The Cleveland-Cliffs Iron Company	Magnetite from open-pit mine (19)	Pellets (66/65)	1 153	1 197
Algoma Ore Division of The Algoma Steel Corp., Ltd.; mines and sinter plant near Wawa, Ont.	Wholly owned	Siderite from underground mine (33)	Siderite sinter (48/48)	1 518	1 865[1]
Caland Ore Co. Ltd.; east arm of Steep Rock Lake, near Atikokan, Ont.	Inland Steel Company	Hematite and goethite from open-pit mine (54)	Pellets (63/63) Concentrate (56/58)	701 818	860 729
Griffith Mine, The; Bruce Lake, 56 kilometres south of Red Lake, Ont.	The Steel Co. of Canada, Ltd.; managed by Pickands Mather & Co.	Magnetite from open-pit mine (23)	Pellets (67/66) Sponge iron (90/82)	1 471 17	1 579[2] 77
Hilton Mines, Ltd., near Shawville, Quebec, 64 kilometres NW of Ottawa	The Steel Co. of Canada Ltd., 50% Jones & Laughlin Steel Corp., 25%; Pickands Mather & Co. (managing agent), 25%	Magnetite from open-pit mine (17)	Pellets (66/66)	785	657
Iron Ore Company of Canada	Labrador Mining and Exploration Company Ltd., 4.73%; Hollinger Mines Ltd., 10.17%; The Hanna Mining Co. (managing agent), 26.37%; Bethlehem Steel Corp. 18.80%; Armco Steel Corp., 5.87%; Lykes-Youngstown Corp., 5.87%; National Steel Corp. of				
1. Schefferville, Quebec Labrador operation		Hematite-goethite-limonite from open-pit mines (54)	Direct-shipping ore (50/54)	4 134	4 125
2. Carol Lake, Labrador operation		Specular hematite and magnetite from open-pit mines (39)	Pellets (66/64) Conc. (66/63)	9 162 6 462	10 085 7 301

Iron Ore Company of Canada (cont'd.)

3. Sept-Iles, Quebec, pellet operation	Canada Limited, 17.62%; Republic Steel Corp., 5.87%; Wheeling-Pittsburgh Steel Corp., 4.70%.	Hematite-goethite-limonite from open-pit mines, Schefferville area Treat-Ore (53)	Pellets (63/61)	3 005	3 585
Marmoraton Mining Co., Division of Bethlehem Chile Iron Mines Company, near Marmora, Ont.	Bethlehem Steel Corp.	Magnetite from open-pit mine (41)	Pellets (66/66)	282	462
National Steel Corporation of Canada, Ltd., Moose Mountain Mine; Sudbury area, 32 kilometres north of Capreol, Ont.	National Steel Corp. of Canada, Limited (The Hanna Mining Co. is the managing agent)	Magnetite from open-pit mine (33)	Pellets (63/62)	673	627
Quebec Cartier Mining Company; Mount Wright near Fermont, Que.	United States Steel Corp.	Specular hematite from open-pit mine (33)	Specular hematite[3] conc. (66/64)	—	14 137[4]
Sidbec-Normines Inc.; Gagnon and Fire Lake, Que.	Sidbec-Dosco Ltd.; 50.1% British Steel Corp. 41.69% Quebec Cartier Mining Co., 8.23%	Specular hematite from open-pit mine (36)	Specular hematite conc. (66/64)	8 267	
Sherman Mine, near Temagami, Ont.	Dominion Foundries and Steel, Limited, 90% Tetapaga Mining Company Limited (wholly-owned subsidiary of The Cleveland-Cliffs Iron Company), 10%. The operation and management of the mine is by Cliffs of Canada Limited, also a wholly-owned subsidiary of The Cleveland-Cliffs Iron Company	Magnetite from open-pit mines (21)	Pellets (66/65)	1 117	1 093
Steep Rock Iron Mines Ltd.; Steep Rock Lake, north of Atikokan, Ont.	Publicly-owned company	Hematite-goethite from open-pit mine (49)	Conc. (58/54) Pellets (63/62)	5 1 122	7 1 363

Table 2. (concl'd)

Company and Property Location	Participating Companies	Material Mined and/or Treated 1976	Product Shipped 1976	Shipments 1975	Shipments 1976
		(% Fe natural)	(% Fe dry/wet)	(000 tonnes)	
Texada Mines Ltd.; Texada Island, B.C.	Kaiser Aluminum & Chemical Corporation	Magnetite and chalcopyrite from open-pit and underground mines (34)	Magnetite concentrate (63/60)	312	388
Wabush Mines; Scully Mine includes mine and concentrator at Wabush, Labrador; Pointe Noire Division includes pelletizing plant at Pointe Noire, Que.	The Steel Co. of Canada Ltd. 25.6%; Dominion Foundries and Steel, Ltd., 16.4%; Youngstown Sheet and Tube Company, 15.6%; Inland Steel Co., 10.2%; Interlake, Inc., 10.2%; Wheeling-Pittsburgh Steel Corp., 10.2%; Finsider of Italy, 6.6%; and Pickands Mather & Co., (managing agent), 5.2%	Specular hematite and some magnetite from open-pit mine (35)	Pellets (66/64) Conc. (66/64)	3 258 18	5 487 —
Wesfrob Mines Limited; Tasu Harbour, Moresby Is., Queen Charlotte Is., B.C.	Falconbridge Nickel Mines Limited	Magnetite and chalcopyrite from open-pit (38) and underground (44) mines	Pellet-feed concentrates (69) Sinter-feed concentrate (60)	610 411	564 344
Byproduct Producers					
Inco Limited	Publicly-owned company	Pyrrhotite flotation concentrates (57) treated	Pellets (67/66)	517	485
Quebec Iron and Titanium Corp.; mine at Lac Tio, Que.; electric smelter at Sorel, Quebec	Kennecott Copper Corp; Gulf & Western Industries, Inc. (The New Jersey Zinc Co.)	Ilmenite-hematite ore (40% Fe, 35% TiO_2) from open-pit mine at Lac Tio, beneficiated and calcined at Sorel	Ilmenite calcine electric smelted to TiO_2 slag and various grades of desulphurized pig iron or remelt iron.	421	467[5]

Sources: Company reports, personal communication.
[1]Includes 150 014 tonnes of regular sinter; 1 710 979 tonnes of superfluxed sinter; 4303 tonnes of crude ore shipped as food supplement to livestock industry. [2]Includes 115 061 tonnes of oxide pellets consumed in the SL-RN direct reduction kiln. [3]Average grade of shipments from Quebec Cartier Mining and Sidbec-Normines. [4]Includes shipments of Sidbec-Normines. [5]Pig iron.
— Nil.

principle used in the Marconaflo system is very simple. When water is injected under pressure into silt, the latter turns into mud that can then be pumped away. So far, the operation has been very effective.

Steep Rock. Remaining ore reserves of 5 million tonnes at Steep Rock are expected to be sufficient to provide pellet feed through most of 1979. At that time, it is possible that the low-grade ore stockpiled by Caland be used in conjunction with ore from Bending Lake. The results of these studies will be known in late 1977.

Griffith's direct-reduction plant. In 1976 the SL-RN direct-reduction plant of Stelco at the Griffith Mine operated from January to March. The plant was then closed because of operating problems. During that period it operated at 80 per cent capacity and produced almost 30 000 tonnes of sponge iron. The plant was reopened later but was finally shut down completely in August. It will reopen in early 1977 but will operate at only 50 per cent capacity. The plant has a rated capacity of 400 000 tonnes of sponge iron a year and in 1977 the company intends to produce some 200 000 tonnes of sponge iron for its Edmonton and Contrecoeur plants, which have a total raw steelmaking capacity of 0.43 million tonnes a year. It uses a mixture of coal and iron pellets to produce sponge iron.

Sudbury Metals Company. The ACCAR direct-reduction plant of Sudbury Metals at Falconbridge, Ontario owned by Allis-Chalmers Corporation and National Steel Corporation, officially opened on May 12, 1976. The plant has a designed capacity of 275 000 tonnes of sponge iron a year. It uses Inco oxide pellets as a feed material and oil and gas as a reductant, and may eventually use solid reductants. Unfortunately the plant was shut down in October following an explosion that occurred while the plant was not in operation. The cause of the explosion was still under investigation at the end of the year.

British Columbia

Texada Mines Ltd. The company ceased operations at its iron ore mine near Gillies Bay, British Columbia on December 17, 1976, when ore reserves were exhausted. Texada Mines started production in 1952 and at the end of 1976 it had produced a total of 10.5 million tonnes of concentrates. All of Texada's production had been sold to Japanese consumers. The mine closure resulted in the loss of 180 jobs.

Wesfrob Mines Limited. To date, Wesfrob Mines has extracted all its iron ore by using open-pit techniques. However, ore reserves accessible by open-pit mining are rapidly approaching depletion and to enable operations to continue beyond 1976, management has decided to develop underground ore. In doing so, production will be extended until at least 1981. It is anticipated that about 5 million tonnes of pellet feed should be economically extractable using underground mining techniques. Further reserves of sinter feed are known to exist but prevailing economics preclude their development.

Table 3. Production and capacity of pig iron and crude steel at Canadian iron and steel plants, 1975-76

	1975	1976p
	(tonnes)	
Pig iron		
Production	9 149 995	9 800 524
Capacity at December 31	10 614 061	12 219 779
Steel ingots and castings		
Production	13 024 876	13 136 076
Capacity at December 31	17 008 353	17 323 871

Source: Statistics Canada.
pPreliminary.

Table 4. Receipts, consumption and stocks of iron ore at Canadian iron and steel plants, 1975-76

	1975	1976p
	(tonnes)	
Receipts imported	4 004 392[1]	3 262 743[2]
Receipts from domestic source	9 568 913[3]	10 057 878[4]
Total receipts at iron and steel plants	13 573 305	13 320 621
Consumption of iron ore	12 674 768[5]	13 694 489[6]
Stocks of ore at iron and steel plants, December 31	4 329 070	4 383 340
Change from previous year	+887 840	+54 270

Source: American Iron Ore Association.
[1]Compared with 4 844 416 tonnes in Table 1. [2]Compared with 3 020 130 tonnes in Table 1. [3]Compared with domestic shipments of 10 117 605 tonnes compiled by Statistics Canada. [4]Compared with 10 409 525 tonnes compiled by Statistics Canada. [5]Compared with 12 847 008 tonnes compiled by Statistics Canada for blast furnace consumption. [6]Compared with 13 697 452 tonnes compiled by Statistics Canada for blast furnace consumption.
pPreliminary.

Other developments

During the year, Combustion Engineering Ltd. of Montreal investigated the possibility of using coal in pelletizing plants as a substitute for oil and gas. The

Table 5. Canadian consumption of iron-bearing materials at integrated* iron and steel plants, 1976

	In Sinter Plants	In Direct Reduction Plants	In Iron and Steel Furnaces: In the Production of Pig Iron	In Iron and Steel Furnaces: In Steel Furnaces	In Iron and Steel Furnaces: Total in Furnaces
			(tonnes)		
Iron Ore					
Crude and concentrates	243 241	—	349 726	23 250	372 976
Pellets	114 641	270 758	10 793 034	66 298	10 859 332
Sinter	93 645	—	1 745 457		1 745 457
Sinter produced at steel plant	—	—	326 498	—	326 498
Direct-reduced iron	—	—	31 149	164 050	195 199
Other iron-bearing materials					
Flue dust	122 556	—	—	—	—
Mill scale, cinder, slag	478 160	—	474 988	496	475 484

Source: Company data.
*Dominion Foundries and Steel, Limited, Hamilton, Ont.; Sidbec-Dosco Limited, Contrecoeur, Que.; Sydney Steel Corporation, Sydney, N.S.; The Algoma Steel Corporation, Limited, Sault Ste. Marie, Ont.; The Steel Company of Canada, Limited, Hamilton, Ont.
— Nil.

study was prompted by recent increases in fuel costs, with possibilities of other major increases in the near future. Even though the price of subbituminous coal has increased considerably in the past two years it is generally agreed that in the long-term the price of coal will not increase as fast as that of oil and gas because world coal reserves are very large while proven reserves of oil and gas are diminishing rapidly. Prices for bunker "C" oil and natural gas delivered to Toronto or Montreal in 1976 were respectively $2.00 and $1.60 per million Btu's. This compares with $2.50 and $3.50 per million Btu's for low- and medium-Btu gas prepared at coal gasification plants.

Arthur G. McKee and Company of Canada Ltd. in a preliminary market study prepared by visiting several small electric steelmakers in Canada indicated that by 1980 some 850 000 tonnes of sponge iron briquettes would be needed in western Canada, and 900 000 tonnes in eastern Canada. This excludes production from both Sidbec and Stelco that will be available for these markets. The cities of Saint John, Sorel and Vancouver were mentioned as possible sites for direct reduction plants. McKee is promoting the use of the Fior process. Fior sponge iron is made from natural fine ores in a fluid-bed reactor, using a hydrogen-rich gaseous reductant such as natural gas, naphtha, heavy fuel oils etc. Reduced iron is then compressed into high-density briquettes for use in steel furnaces.

Metallurgical work was conducted by The Canada Centre for Mineral and Energy Technology (CANMET) laboratories in Ottawa on iron material from the Peace River area of Alberta. The metallurgy of this material is complex, as it has a high content of silica, phosphorus and sulphur.

During the year the Department of Transport investigated the possibility of increasing tolls on the St. Lawrence Seaway and the Welland Canal in order to cover operating and maintenance costs. As far as iron ore is concerned, toll payments represented about 2.0 per cent of the value of iron ore in 1976. A 60 per cent toll increase would represent an increase of 1 per cent on the cost of iron ore. Tolls on the Seaway have not increased since 1959, but prices of iron ore have increased substantially in the past two years. This means that in relative terms, tolls have decreased because the latter are based on tonnages rather than on value. A 50- to 100-per cent toll increase is predicted for 1978. Such an increase may affect the flow of iron ore through the St. Lawrence River. For instance, it may become more economic to ship iron ore originating from the Quebec-Labrador region via the East Coast ports rather than the Seaway to steel centres such as Wheeling West Virginia, and Johnstown and Pittsburg in Pennsylvania. Also, the toll increase would make Brazilian and West African ores, which are not shipped to the Lake Erie steelmaking region through the Seaway but by ocean and rail transport, more competitive in relation to Quebec-Labrador ores which are shipped by the Seaway route.

Iron ore pricing in North America

In the North American Great Lakes market, Canadian and United States iron ore products are sold at, or near, the Lake Erie base prices c.i.f. rail of vessel. The published Lake Erie base prices that apply to concentrates and pellets do not fluctuate in response to temporary changes in supply and demand of iron ore but are adjusted periodically to reflect changes in the costs of energy, labour, raw materials, transportation etc. The prices are established mainly by The Hanna Mining Company, The Cleveland-Cliffs Iron Company and Pickands Mather & Co. which are major merchant-ore mining firms and management representatives for a large number of captive iron ore mines in Canada and the United States. The prices are designed to cover operating costs and provide a small profit at the mine operator's level. In Canada about 60 per cent of the sales are captive to Canadian and United States steel companies, the remainder being sold on the open market. This percentage is likely to decrease considerably in the future as Canadian steel producers continue to invest in United States iron ore mining operations and as most production from new mines, developed mainly by U.S. firms in Quebec-Labrador, is exported abroad.

Following is a simplified price calculation of pellets delivered to Algoma at Sault Ste. Marie and originating

Table 6. Sourcing patterns of major Canadian steel producers (1976 to 1979)

Mine	Ownership (%)	Capacity in 1976 (million tonnes/ year)	Product	Share of Capacity and/or Regular Supplies	Notes
Stelco					
Griffith	100	1.36	pellets	1.36	
Wabush	26	5.53	pellets	1.45	
Hilton	50	0.91	pellets	0.45	Depleted early 1977
Erie	10	9.34	pellets	0.93	
Tilden[1]	10	4.00	pellets	0.40	Expansion to 8.0 million tonnes a year in 1979
Eveleth[2]	nil	2.40	pellets	nil	Expansion to 6.0 million tonnes a year in 1977
Hibbing[3]	10	5.40	pellets	0.54	Expansion to 8.1 million tonnes a year in 1979
Dofasco					
Wabush	16	5.53	pellets	0.91	
Sherman	90	1.00	pellets	0.91	
Adams	100	1.00	pellets	1.00	
Eveleth[4]	nil	2.40	pellets	nil	Expansion to 6.0 million tonnes a year in 1977
Algoma					
Algoma ore	100	1.63	sinter	1.63	
Steep Rock[5]	nil	1.27	pellets	1.27	Depleted in 1979
Inco	nil	0.36	pellets	0.36	
Tilden[6]	30	4.00	pellets	1.20	Expansion to 8.0 million tonnes a year in 1979
Bending Lake[7]	nil	nil	pellets	nil	Expected start-up in 1979 at a capacity of 2.2 million tonnes a year.
Sidbec-Dosco					
Sidbec-Normines	50	6.00	pellets	3.0	Start-up in 1977

Source: Mineral Development Sector.

Note: Sydney Steel does not have any ownership share in any iron ore mine, and purchases its iron ore requirements (pellets) mainly from Iron Ore Company of Canada. [1] 15% of total capacity in 1979. [2]23.5% of expansion capacity. [3]6.67% of total capacity in 1979. [4]16% of expansion capacity. [5]Canadian Pacific Investment Ltd. owns 51% of Algoma and 68% of Steep Rock. [6]30% of total capacity in 1979; will also purchase 600 000 tonnes a year from Tilden [7]Owned by Jones & Laughlin and optioned to Algoma.

from two different mining areas, one in Canada and one in the United States:

Mine value and price per tonne of Steep Rock pellets delivered on dock steelworks of Algoma Steel, Sault Ste Marie, Ontario, effective September 1, 1976

Pellet — iron analysis natural	62.3%
Published price per iron unit, rail of vessel at lower lake ports	$U.S. 0.523
	($ U.S.)
Price rail of vessel lower lake ports	32.600
Less unloading hold to rail of vessel	0.482
Price hold of vessel, lower lake ports	32.118
Less lake freight Thunder Bay to lower lake ports	3.673
Price hold of vessel, Thunder Bay	28.445
Less rail freight Atikokan to Thunder Bay	2.942
Mine value railway cars Atikokan	25.503
Add rail freight Atikokan to Thunder Bay	2.942
Price hold of vessel, Thunder Bay	28.445
Add lake freight Thunder Bay to Sault Ste. Marie	2.018
Price on dock steelworks, Sault Ste. Marie	30.463

Mine value and price per tonne of Tilden pellets delivered on dock steelworks of Algoma Steel, Sault Ste. Marie, Ontario, effective August 16, 1976

Pellet — iron analysis natural	63.03%
Published price per iron unit, rail of vessel at lower lake ports	$U.S. 0.523
	($ U.S.)
Price rail of vessel lower lake ports	32.965
Less unloading hold to rail of vessel	0.482
Price hold of vessel lower lake ports	32.483
Less lake freight, Marquette to lower lake ports	3.287
Price hold of vessel, Marquette	29.196
Less rail freight Mine to Marquette	1.191
Mine value railway cars Tilden Mine	28.005
Add rail freight Mine to Marquette	1.191
Price hold of vessel, Marquette	29.196
Add lake freight Marquette to Sault Ste. Marie	1.556
Price on dock steelworks, Sault Ste. Marie	30.752

World developments

In 1950 there was no commercial iron ore pellet production. By 1975 pellet production capacity in the noncommunist world was around 150 million tonnes, which represented about 25 per cent of iron ore production. Plants under construction will add 64 million tonnes in two or three years. Of the new capacity, the United States will account for 25 million tonnes, and Brazil 18 million tonnes. This trend is likely to continue because pellets increase blast furnace output and are environmentally more attractive than sinter plants in heavily-populated areas such as Japan and Europe. Demand for pellets will also increase as more direct-reduction plants are being built.

In Canada and the United States 70 to 75 per cent of the iron ore consumed by steel mills is in the form of

Table 7. Lake Erie base prices of selected ores, 1964-77

	1964-69	1970	1971 and 72	1973[1]	1974[2]	1975[3]	1976[4]	1976[5]	1977[6]
	($ U.S. per tonne)								
Mesabi Non-Bessemer	10.38	10.63	10.99	11.52	14.82	18.20	18.94	19.94	20.84
Manganiferous	—	—	—	—	—	18.45	19.19	20.18	20.18
Mesabi Bessemer (+ phos. premium)	10.53	10.77	11.14	11.67	14.80	18.35	19.09	20.07	20.07
Old Range Non-Bessemer	10.63	10.87	11.24	11.77	14.90	18.45	19.19	20.18	21.09
Old Range Bessemer	10.78	11.02	11.38	11.92	15.05	—	—	—	—
High Phosphorous	10.38	10.63	10.63	—	—	—	—	—	—
Pellets (per tonne natural unit)[7]	0.248[8]	0.262	0.276	0.286[9]	0.374	0.464	0.497	0.522	0.546

Sources: Skilling's Mining Review; Mineral Development Sector.
[1]Increase effective January 1973. [2]Increase effective August 1974. [3]Increase effective July 1975. [4]Increase effective January 1976. [5]Increase effective August 1976. [6]Increase forecast for 1st quarter, 1977. [7]Equals 1% of a tonne, i.e., 10.0 kg. for a tonne unit. An iron ore containing 60% Fe therefore has 60 units. [8]Price applicable for years 1964 to 1969. [9]Increases effective March 1973 and October 1973.
— Nil.

pellets. In Japan and Western Europe, however, this percentage is much lower; 15 and 6 per cent respectively.

Pellets requirements in North America until 1985 will be met by existing facilities and new plants under construction in North America, while in Western Europe pellets requirements will be met mostly by plants currently operating in Sweden and Norway and by new plants being built in Western Europe, Canada, Brazil and Liberia. The Japanese requirements will be met by plants operating in Australia and new ones being built in Brazil.

In 1966 Brazil produced some 23 million tonnes of iron ore and ranked sixth in the non-communist world; in 1976 the country produced 75 million tonnes and ranked third. The largest producer in Brazil is Companhia Vale do Rio Doce (CVRD), which in 1975 shipped 52.2 million tonnes, mainly to Japan, West Germany, the United States, France and Italy. The company's goal is to export 100 million tonnes, or about twice as much as Canada, in 1985.

There are three mammoth projects under way in Brazil. One of them is being developed by Samarco Mineracao S.A., owned by Samitri (51 per cent) and Utah International Inc. (49 per cent). The company will build the longest slurry pipeline in the world (402 km). The pipeline, capable of transporting 10 million tonnes of iron ore a year, is scheduled to begin operations in 1977. Concentrates (56 per cent solids and 44 per cent water) from the Itabira mines will be transported near the coast for pelletizing. The second project is the Carajas mining project. Even though financing is not complete, the voting shares will most likely be held by CVRD and U.S. Steel. Output of iron ore is scheduled to reach 50 million tonnes a year by 1985. U.S. Steel intends to buy 10 million tonnes a year and the Nippon Steel Corporation group, British Steel, and Altos Hornos de Vizcaja of Spain will subscribe the non-voting shares, entitling them to purchase up to 25 million tonnes a year. France, Italy and West Germany may also acquire rights to buy what is left. A 900-km electrified railway will be built to link the Carajas ore deposits to the port of Itaqui near Saô Luis. The third project is a steel mill to be constructed at Itaqui, following studies by Siderurgis Brasileira S.A. and Nippon Steel. The mill will utilize the Carajas iron ore, and coal from southern Brazil, the United States, Australia and Poland. A first-phase capacity of 4 million tonnes of semis a year is scheduled to begin in 1980, increasing to 8 million tonnes in 1983 and 16 million tonnes in a final stage. Brazil and Japan will absorb 25 per cent each and remainder will be exported.

Long-term supplies and strategies

There are five major steel-consuming regions in the world: United States/Canada, the U.S.S.R., Japan, Eastern Europe and Western Europe. As far as iron ore resources are concerned, only two of these steel-consuming regions have enough ore to supply their needs for several years; United States/Canada and the U.S.S.R. Japan is almost totally dependent upon overseas material, Western Europe must import a substantial amount of iron ore and Eastern Europe relies mainly on the U.S.S.R.

For several years Japanese steelmakers have relied mainly on Australian iron ore for their supplies. In the early 1970s, however, Japanese imports from Brazil increased rapidly and during 1976 a group of Japanese steelmakers was able to sign a 15-year contract with CVRD for the supply of 376 million tonnes of iron ore having a sales value of $6.7 billion at current prices. The sale includes the supply of 285 million tonnes of direct shipping ore valued at $4 billion, and a contract for the sale of 91 million tonnes of pellets valued at $2.7 billion, or $29.67 a tonne. Currently the Japanese industry consumes 140 million tonnes of iron ore a year, of which Brazil supplies about 13 per cent. With the signing of the contract Brazil will be supplying about 25 per cent of total Japanese requirements by 1980.

Table 8. World iron ore production, 1974-76

	1974	1975^p	1976^e
	(000 tonnes)		
U.S.S.R.	224 883	232 800	238 000
Australia	96 688	99 400	102 000
United States	85 917	81 351	79 000
Brazil	79 973	69 640	75 000
People's Republic of China	51 000	65 024	66 000
France	54 730	50 142	44 000
Canada (shipments mine)	46 785	44 893	57 000
India	34 230	40 271	41 000
Liberia	36 000	27 127	23 000
Sweden	36 153	32 639	29 000
Venezuela	26 408	24 790	17 000
Republic of South Africa	11 734	12 240	. .
Chile	10 297	10 500	. .
Peru	9 563	9 600	. .
Mauritania	8 280	8 500	. .
Spain	8 613	8 217	. .
North Korea	8 100	8 200	. .
Mexico	4 902	5 550	. .
Others	61 558	58 350	116 000[1]
Total	895 814	891 793	887 000

Sources: For Canada, Statistics Canada. For other countries, *Metal Bulletin*. U.S. Bureau of Mines (Commodity Data, Summaries, 1977).
^{p}Preliminary; ^{e}Estimated; . . Not available.
[1]Others includes estimates for countries for which figures are not available.

cent for iron ore is predicted in early 1977.

To cover operating and maintenance costs on the St. Lawrence Seaway, tolls are expected to be increased by 50 to 100 per cent in late 1977 or in 1978.

In the longer term, increased tonnages of iron ore will come largely from expansions of existing facilities because expansions can be accomplished for much less than the cost of new ventures.

New developments in Canada will be slowed somewhat by increased competition from Brazil. The Carajas project alone is aimed at producing 50 million tonnes of ore a year starting in 1985 and most of the production will be for export to Europe, a major market for Canadian ore.

Canada and the United States have diminishing reserves of oil and gas while coal is still very abundant. The future of oil and gas prices is also uncertain. For these reasons coal, and perhaps even lignite gasification will become increasingly attractive in pelletizing and as reducing agents in direct-reduction plants.

In transportation, the use of pipelines is expected to increase mainly because maintenance costs are lower than for railways. Electrification of railways, using hydro- or coal-generated electricity, is also expected to increase in Canada and the United States because of uncertainties about future prices of oil.

In the field of steelmaking and energy conservation it will soon be possible to produce pellets and feed them "hot" to direct-reduction plants. The next step will probably be the continuous melting of reduced pellets in electric furnaces.

Table 10. Energy characteristics of alternative direct-reduction processes

Process	Allis Chalmers	Armco	Fior	HIB	HYL	Krupp	Midrex	Purofer	SL-RN
Process Type	Kiln	Shaft furnace	Fluid bed	Fluid bed	Retort	Kiln	Shaft furnace	Shaft furnace	Kiln
Reductant Source	Natural gas Oil Coal	Natural gas	Natural gas	Natural gas	Natural gas	Non-coking coal	Natural gas	Natural gas	Non-coking coal
Energy (for Reduction) (million Btu/ton)	13-20[1]	12.7	14.6	18.0	15.4	13-20[1]	12.0	13.1	13-20[1]
Power Consumption (kWh/ton)	45	33	40	N/A	20	40	135	100	36
Total Energy Consumption (million Btu/ton)	13-20[1]	12.8	14.7	N/A	15.5	13-20[1]	12.1	13.2	13-20[1]
Type of ore	Lumps Pellets	Pellets Some lumps	Fines	Fines	Lumps Pellets	Lumps Pellets Fines	Pellets Some lumps	Pellets Some lumps	Lumps Pellets Fines

Source: Company publications.
[1]Dependent on nature of solid reductant.

Table 11. Direct-reduction plants in the world, and countries with potential for direct-reduction plants, 1976

Country	Population 1971	Crude Steel Production 1970	Crude Steel Consumption 1970	Iron Ore Reserves 1970	Know Recoverable Reserves: Coking Coal	Know Recoverable Reserves: Non-Coking Coal 1973	Know Recoverable Reserves: Total	Reserves 1976: Oil	Reserves 1976: Gas	Resources 1973: Hydro[1]	Resources 1973: Uranium	Direct Reduction Plants in operation, end of 1976		Plants under construction and planned for 1980	
	(millions)	(thousand tonnes)		(million tonnes)	(million tonnes)			10^6 tonnes	10^9 cu. metres	MW	10^3tonnes at $26/t	(thousand tonnes)			
People's Republic of China	772	19 000	23 000	6 000	32 000	48 000	80 000	2 700	710	330 000	. .	—	—	—	—
India	573	6 500	6 000	8 600	4 500	7 000	11 500	120	68	70 000	. .	—	—	—	—
U.S.S.R.	242	116 000	109 000	110 000	30 000	106 000	136 000	10 900	22 700	270 000	. .	—	—	—	2 500 g
United States	205	120 000	127 000	8 000	39 000	142 000	181 000	4 460	6 100	187 000	330	130 c;	1 030 g	100 c;	900 g
Indonesia	119	. . .	. . .	. . .	. . .	1 000	1 000	1 900	425	30 000	. .	—	—	2 300 g	—
Pakistan	117	20	700	500	. .	. .	200	. . .	465	20 000	. .	—	—	—	—
Japan	104	93 000	70 000	500	500	1 000	200	. . .	2	50 000	3	1 200 c;	150 o	250 c;	240 o
Brazil	92	5 300	5 400	60 000	. . .	1 800	1 800	105	26	90 000	2	60 c;	250 g	250 o	—
Nigeria	66	. . .	. . .	. . .	. . .	. . .	200	2 730	1 255	1 500	40	—	—	—	—
W. Germany	61	45 000	40 000	3 000	18 000	21 500	39 500	50	235	4 400	. . .	550 g	—	1 200 g	—
U.K.	56	26 000	25 000	3 100	1 600	2 200	3 800	2 160	1 400	2 500	. . .	—	—	1 600 g	—
Italy	54	17 000	21 000	. . .	. . .	. . .	. . .	47	200	19 000	1	40 c	—	—	—
France	51	23 800	23 000	6 500	350	150	500	12	150	21 000	35	—	—	—	—
Mexico	48	3 800	3 600	600	150	500	650	1 280	340	20 000	1	1 440 g	—	625 g	—
Egypt	35	450	900	400	. . .	. . .	. . .	530	113	3 800	. .	—	—	—	—
Poland	33	11 700	12 000	400	5 000	17 300	22 300	40	57	3 800	. .	—	—	—	—
Iran	28	. . .	1 600	150	. .	. .	200	8 700	9 300	10 000	. .	—	—	2 530 g	—
Argentina	25	1 800	3 400	250	100	. . .	100	330	204	48 000	13	330 g	—	420 g	—
Canada	22	11 000	11 000	34 000	5 000	600	5 600	960	1 512	95 000	186	400 g;	360 c;	600 g	—
Republic of												240 g/o	—	—	—
South Africa	21	4 700	4 800	2 400	150	10 000	10 150	. . .	. . .	4 600	200	1 150 c	—	300 c	—
Zaire	18	. . .	. . .	. . .	. .	. .	. .	68	1	132 000	2	—	—	—	—
E. Germany	18	5 100	9 000	. . .	. . .	25 300	25 300	. . .	. . .	. . .	. .	—	—	—	—
Algeria	14	50	700	600	. . .	. . .	. . .	1 000	3 600	4 800	. .	—	—	—	—
Peru	14	200	400	1 000	. .	. .	100	104	64	12 000	. .	—	—	100 c	—
Australia	13	7 000	6 000	35 000	9 000	16 000	25 000	230	920	8 600	120	—	—	—	—
Malaysia	12	. . .	. . .	100	. . .	. . .	. . .	340	425	1 300	. .	—	—	—	—
Venezuela	11	1 000	1 500	2 000	. . .	. . .	. . .	2 390	1 200	12 000	. .	1 050 g	—	4 020 g	—
Belgium and Luxembourg	10	18 000	5 000	260	. .	. .	130	. . .	. . .	12 000	. . .	—	—	—	—
Iraq	9	. . .	500	. .	. .	. .	. .	4 600	770	2 000	. . .	—	—	1 600 g	—
Sweden	9	5 500	6 000	3 400	. . .	. . .	. . .	. . .	. . .	20 000	. . .	260 c	—	—	—
Ecuador	7	. . .	200	. .	. .	. .	. .	330	140	21 000	. .	—	—	—	—
Syria	6	. . .	. . .	. .	. .	. .	. .	303	35	. .	. .	—	—	—	—
Saudi Arabia	6	. . .	. . .	. . .	. .	. .	. .	20 100	2 900	1 000	. .	—	—	—	—
Rhodesia	5	140	150	400	. .	. .	1 400	. .	. .	5 000	. .	—	—	—	—
Norway	4	870	2 000	740	. . .	. . .	. . .	950	700	30 000	. .	—	—	—	—
New Zeland	3	. . .	1 000	600	. . .	200	200	. . .	140	10 000	. .	120 c	—	—	—
United Arab Emirates	0.2	. . .	. . .	. . .	. .	. .	. .	5 000	6	. .	. .	—	—	—	—
Quatar	0.1	. . .	. . .	. . .	. .	. .	. .	790	210	. .	. .	—	—	400 g	—
Kuwait	0.9	. . .	. . .	. . .	. .	. .	. .	9 200	900	. .	. .	—	—	—	—
Gabon	0.5	. . .	. . .	1 000	. .	. .	. .	300	70	18 000	20	—	—	—	—
Bahrain	0.2	. . .	. . .	. . .	. .	. .	. .	40	160	. .	. .	—	—	—	—
Oman	0.7	. . .	. . .	. . .	. .	. .	. .	800	60	. .	. .	—	—	—	—
Libya	2	. . .	. . .	. . .	. .	. .	. .	3 500	750	. .	. .	—	—	—	—
Trinidad-Tobago	1.2	. . .	. . .	. . .	. .	. .	. .	100	110	. .	. .	—	—	420 g	—

Source: Compiled by Department of Energy, Mines and Resources, Ottawa, from various publications.

[1]Installed and installable capacity.

. . Not available; . . . Negligible; o Oil; g Natural gas; c Coal; — None.

Iron and Steel

MICHAEL K. McMULLEN

Although the economic climate in Canada improved in 1976 *vis-a-vis* 1975 this was not matched by the performance of the Canadian steel industry. Whereas the Gross National Product (GNP) increased by 4.9 per cent, apparent steel consumption fell fractionally to 9.8 million tonnes* and crude steel production increased by less than one per cent to 13.1 million tonnes. Demand for steel products was generally low throughout the year, although there were some encouraging signs early in 1976 that demand would pick up by mid-year. However, this was not the case and demand slowed markedly toward the end of the year.

The consumer goods sector was an exception, being buoyant throughout 1976, particularly due to the strong sales of North American automobiles. Thus, demand for flat rolled products showed a strong gain over 1975. On the other hand, the capital goods and construction markets remained depressed. Demand for structurals, rods and bars was poor. This indicated a lack of investment and reflected the uncertainty of many manufacturers concerning the short- and medium-term outlook for the performance of the Canadian economy.

The variation in demand levels for different steel products resulted in the variable performances of Canada's "Big Three" steel companies in 1976. Dominion Foundries and Steel, Limited (Dofasco), which produces mainly flat-rolled steel products, experienced an excellent year in response to demand by the automobile industry and, to a lesser extent, the appliances industry. By contrast, The Algoma Steel Corporation, Limited, which produces significant tonnages of structural steel and related products, struggled under the adverse market conditions pervasive in the capital goods sector. The Steel Company of Canada, Limited (Stelco), which produces the largest range of steel products in Canada, had a reasonable year, with the high demand for flat-rolled products, fortunately, more than compensating for slack demand for long products. The activity of many regional steel producers remained at very depressed levels.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Internationally, the world steel industry improved its performance over the disastrous results of 1975. However, in many countries, and most notably in Europe, capacity utilization remained poor and consequently many firms were unprofitable. Many countries attempted to step up export sales in order to maintain certain production levels. Consequently, the competition became intense and prices fell.

By the end of the year imports into Canada were increasing, particularly in the markets at the east and west coasts. Moreover, the prices of these products were affecting price levels throughout the country. Many offerings of offshore steel were being made at as much as 30 per cent below domestic price levels. This led many domestic producers to voice their concerns that certain steel products were being dumped in Canada, *i.e.*, sold at prices less than those prevailing in the countries of origin. At year-end several companies were in the process of submitting complaints to the Anti-Dumping Tribunal.

Outlook

The market for steel products in Canada in 1977 is expected to be unsettled due to the sluggish nature of the Canadian economy. It is hoped that economic activity in Canada will increase at a rate at least sufficient to provide some growth in the demand for steel products in 1977. However, high levels of unemployment and inflation, large trade deficits, increasing energy costs, concerns over availability and the cost of capital, declining productivity and the situation of the Canadian dollar in the international money market are problems overhanging the Canadian economy, and thus the demand for steel. Nevertheless, the Canadian steel industry should do a little better than those of many industrialized countries around the world. The demand for steel from the automobile industry is expected to remain firm and provide one of only a few growth sectors for steel in 1977. Increased activity in the construction and capital goods market is hoped for,

Table 1. Canada, general statistics of the domestic primary iron and steel industry, 1974-76

		1974	1975	1976[p]
Production				
Volume indexes				
Total industrial production	1971 = 100	120.0	114.4	119.8
Iron and steel mills[1]	1971 = 100	123.0	111.1	113.7
		($ million)	($ million)	($ million)
Value of shipments, iron and steel mills[1]		3 036.8	3 202.9	3 461.6
Value of unfilled orders, year-end, iron and steel mills		600.5	556.9	448.3
Value of inventory owned, year-end, iron and steel mills		600.3	920.9	970.0
Employment, iron and steel mills[1]		(number)	(number)	(number)
Administrative		10 275	10 620	10 462
Hourly rated		42 233	40 930	39 251
Total		52 508	51 550	49 713
Employment index, all employees	1961 = 100	152.7	149.9	144.6
Average hours per week, hourly rated		40.0	39.7	39.7
		($)	($)	($)
Average earnings per week, hourly rated		216.40	240.58	278.30
Average salaries and wages per week, all employees		227.78	256.25	295.15
Expenditures, iron & steel mills[1]		($ million)	($ million)	($ million)
Capital: on construction		81.3	111.0	108.6
on machinery		328.4	430.7	334.2
Total		409.7	541.7	442.8
Repair: on construction		24.5	26.9	29.8
on machinery		277.6	341.1	378.0
Total		302.1	368.0	407.8
Total capital and repair		711.8	909.7	850.6
Trade, primary iron and steel[2]				
Exports		598.0	585.1	655.0
Imports		1 174.2	819.5	603.2

Source: Statistics Canada.
[1]S.I.C. Class 291 — Iron and Steel Mills: covers the production of pig iron, steel ingots, steel castings, and primary rolled products, sheet, strip, plate, etc. [2]Includes pig iron, steel ingots, steel castings, semis, hot- and cold-rolled products, pipe and wire. Excludes sponge iron, iron castings and cast iron pipe. Compiled by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[p]Preliminary.

although the prospects do not appear overly bright. It is expected that total crude steel production will increase by about 3 per cent to 13.5 million tonnes. Producer shipments and apparent steel consumption should also increase. As a result of increasing sales activity in Canada by offshore steel suppliers, many selling products at distressed prices, imports are forecast to increase in 1977. Correspondingly, exports may be hard pressed to match 1976 levels.

The short-term outlook remains unclear. Many companies have expanded capacity to meet anticipated demand that has not materialized and the soft markets of the past two years have caused many companies to experience unsatisfactory financial results. Unless there is a resurgence of a strong market for all types of steel, several of these companies may be forced to take strong actions just to stay in business. This could result in reducing output and laying off employees. A continuing poor market demand, combined with increasing labour and raw material input costs and increased competition from low-priced imports, could spell severe financial difficulties for some companies.

Although steel demand will grow in the medium to long term, it now appears that the growth rate will be

Table 2. Canada, pig iron production, shipments, trade and consumption, 1974-76

	1974	1975	1976[p]
		(tonnes)	
Furnace capacity, January 1[1]			
Blast	9 498 224	10 001 711	11 607 429
Electric	612 350	612 350	612 350
Total	10 110 574	10 614 061	12 219 779
Production			
Basic iron	8 676 722	8 587 470	9 166 807
Foundry iron	775 216	562 525	633 717
Malleable iron[2]	..	..	..
Total	9 451 938	9 149 995	9 800 524
Shipments			
Basic iron	111 723	83 203	106 571
Foundry iron[3]	751 115	500 252	589 900
Total	862 838	583 455	696 471
Imports			
Tonnes	2 243	4 078	8 836
Value ($000)	455	884	1 652
Exports			
Tonnes	517 441	406 272	281 557
Value ($000)	61 179	78 202	45 918
Consumption of pig iron			
Steel furnaces	8 700 637	8 495 093	8 971 013
Iron foundries	307 569	269 402	289 454
Consumption of iron and steel scrap			
Steel furnaces	6 986 817	6 612 201	6 336 170
Iron foundries	1 238 798	1 122 809	1 288 016

Sources: Statistics Canada; *Primary Iron and Steel* (monthly); *Iron and Steel Mills* (annual) and *Iron Castings and Cast Iron Pipes and Fittings* (monthly).

[1]The capacity figures as of January 1 in each year take into account both new capacity and obsolete capacity anticipated for the year. [2]Included under "Foundry iron". [3]Includes malleable iron.

[p] Preliminary; .. Not available.

significantly less than had been generally forecast in 1974 and 1975. For example, the trend to smaller and lighter automobiles will dictate less steel per unit than is presently the case. If investment for new plant and equipment continues to lag or stabilize at a lower level of activity than in the 1960s, forecast steel requirements will be less. Also, availability of energy and its price level is another factor now acting on the demand for steel. It now appears that in the period to 1985 the Canadian industry may be characterized by less than desirable capacity utilization and with earnings insufficient to create the capacity needed after 1985.

Production, shipments and consumption

Crude steel production increased marginally to 13.1 million tonnes in 1976 from 13 million tonnes in 1975. Steel shipments from plants increased by 3.7 per cent to about 10 million tonnes, although disposition of rolled steel products to domestic markets declined by 2 per cent to 8.5 million tonnes. Apparent consumption of steel increased fractionally to 9.8 million tonnes.

Basic oxygen production amounted to 7.9 million tonnes, up from 7.3 million tonnes in 1975. This type of steelmaking accounted for roughly 60 per cent of total

Table 3. Canada, crude steel production, shipments, trade and consumption, 1974-76

	1974	1975	1976p
		(tonnes)	
Furnace capacity January 1[1]			
Steel ingot			
Basic open-hearth	3 742 137	3 742 137	3 742 137
Basic oxygen converter	9 026 488	9 186 153	9 267 799
Electric	3 506 995	3 719 457	3 894 997
Total	16 275 620	16 647 747	16 904 933
Steel castings	357 340	360 606	418 938
Total furnace capacity	16 632 960	17 008 353	17 323 871
Production			
Steel ingot			
Basic open-hearth	3 425 220	3 079 115	2 971 118
Basic oxygen	7 354 116	7 304 920	7 945 811
Electric	2 642 861	2 423 740	2 052 621
Total	13 422 197	12 807 775	12 969 550
Continuously cast in total	1 843 179	1 739 124	1 533 892
Steel castings[2]	201 248	217 101	166 526
Total steel production	13 623 445	13 024 876	13 136 076
Alloy steel in total	1 518 669	1 247 038	1 591 361
Shipments from plants			
Steel castings	188 959	195 048	156 861
Rolled steel products	10 377 492	9 481 983	9 820 728
of which steel ingots are	454 495	362 488	453 965
Total	10 566 451	9 677 031	9 977 589
		(000 tonnes)	
Exports, equivalent steel ingots	1 668.8	1 163.6	1 844.0
Imports, equivalent steel ingots	3 603.1	1 712.9	1 385.7
Indicated consumption, equivalent steel ingots	15 557.7	13 574.2	12 677.8

Source: Statistics Canada.
[1]The capacity figures as of January 1 in each year take into account both new capacity and obsolete capacity anticipated for the year. [2]Produced mainly from electric furnaces.
pPreliminary.

steel production. Electric steel and steel castings production at 2.2 million tonnes was down nearly 400 000 tonnes. Basic open-hearth production was off by about 100 000 tonnes to 3.0 million tonnes.

Average ingot steel furnace capacity utilization decreased marginally to 76.7 per cent during the year. This compares with 76.9 per cent in 1975 and 82.5 per cent in 1974. Some of the 1976 experience can be attributed to some new capacity not being available for the entire year and to capacity affected by strikes. However, it also reflects measures to reduce operating levels because of the sluggishness in many steel-product markets that existed for much of the year.

Pig iron production (hot metal) increased 7.1 per cent to 9.8 million tonnes, reflecting somewhat the rise in blast furnace capacity. The bulk of the pig iron is produced and consumed by the integrated steelmakers. About 7 per cent, some 696 000 tonnes, were cast and shipped, mainly to foundries. With extra pig iron available, the demand for ferrous scrap declined overall by some 100 000 tonnes to 7.6 million tonnes. Scrap consumption actually increased for iron foundries but steel furnace use was off by some 276 000 tonnes. This decline affected the scrap dealers as prices fell during the year. At year-end, prices were some $20 per tonne lower than they had been in April.

Table 4. Producer shipments[1] of rolled steel[2], 1975-76

	1975	1976[p]	% Growth
	(000 tonnes)		
Ingots and semis	362.5	454.0	+25.2
Rails	337.1	352.7	+ 4.6
Wire rods	572.3	729.4	+27.5
Structural shapes	659.1	619.0	− 6.1
Concrete reinforcing bar	554.7	484.7	−12.6
Other H.R. bars	862.2	918.0	+ 6.5
Track material	79.1	73.0	− 7.7
Plate	1 456.5	1 072.0	−26.4
Hot-rolled sheet and strip	2 229.9	2 450.0	+ 9.9
Cold finished bars	79.9	76.2	− 4.6
Cold reduced sheet, strip, other and coated	1 522.8	1 764.8	+15.9
Galvanized sheet and strip	765.9	826.9	+ 8.0
Total	9 482.0	9 820.7	+ 3.6
Alloy steel in total shipments	682.2	699.7	+ 2.6

Sources: Statistics Canada; *Primary Iron and Steel* (monthly).
[1]Includes producer exports. [2]Includes ingots and semis, but not steel castings; comprises both carbon and alloy steels.
[p]Preliminary.

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Producer shipments of rolled steel in 1976 amounted to 9.8 million tonnes, an increase of 3.6 per cent compared with 1975. Shipments were up for most groups, including 27.5 per cent for wire rods, 25.2 per cent for ingots and semis, and 15.9 per cent for cold-reduced sheet and strip. The largest sector, hot-rolled sheet and strip, was up by 9.9 per cent to nearly 2.5 million tonnes. Shipments of plate and concrete reinforcing bars declined by 26.4 per cent and 12.6 per cent, respectively. Steel exports were up by nearly two-thirds to 1.3 million tonnes.

Domestic disposition of rolled sheet production (Table 5) declined by 2 per cent during the year. However, a bright spot was the consumer goods market, which was fairly buoyant during the year, particularly due to the automobile market. Steel consumption increased significantly as sales of new automobiles and trucks were strong throughout the year. Other segments of the transportation sector did not fare as well, particularly shipbuilding, railroad cars and locomotives. The capital goods and construction sectors remained poor, reflecting lack of investment for business expansion.

Disposition by wholesale warehouses and steel service centres was off by nearly 10 per cent to 1.2 million tonnes. Pipes and tubes, another large market for steel, declined by nearly 17 per cent to 1.2 million tonnes as several pipeline projects were being completed. This sector should benefit from the pipeline activity expected to develop in northern Canada for the movement of natural gas to southern markets. The wire and wire products industry continues to expand as deliveries rose by 11.5 per cent to nearly 688 000 tonnes in 1976.

Trade

Exports of steel by Canadian producers increased by some 39 per cent to 1.8 million tonnes in 1976. The value of the exports increased by approximately 12 per cent to $655 million. Semi-finished steel, including castings, increased to nearly 153 000 tonnes from 62 000 tonnes in 1975. Finished steel (hot- and cold-rolled products) increased by over 50 per cent to 1.3 million tonnes, with hot-rolled sheet and strip and wire rods showing large gains. Fabricated steel products fell by about 8 per cent to 368 000 tonnes, mainly due to a decline in pipe sales. Approximately two-thirds of total export trade went to the United States, Canada's traditional market. Shipments were up sharply to the European Economic Community (EEC) as exports jumped from 33 000 tonnes in 1975 to nearly 238 000 tonnes in 1976.

Imports fell by some 18 per cent to 1.3 million tonnes, although the value declined only fractionally to $598 million. Although imports were down, Japan increased its shipments to Canada by over 30 per cent to some 434 000 tonnes. Most product lines declined, with the exception of hot-rolled structurals and bars and several cold-rolled products, notably galvanized products. Towards the end of the year imports were increasing and orders for forward delivery in 1977 were said to be mounting. Concern was being shown by Canadian producers as many of these offshore quotations appeared to be at distressed price levels, thus possibly indicating dumping.

Investment and corporate development

Expenditures by the Canadian steel industry for capital and repair declined by some 6.5 per cent in 1976 to 850.6 million. Repair expenditures of $407.8 million increased by nearly 11 per cent; however, capital expenditures decreased by 18 per cent to $442.8 million (Table 1). The decline in capital spending was due in part to the completion of major projects, but mainly to cutbacks in spending and to the lengthening of some companies' expansion schedules due to poor marketing conditions for certain steel products. Nevertheless, capital expenditures are still high in relation to the years prior to 1975 and indicate confidence in the long-term growth potential for steel in Canada.

The Steel Company of Canada, Limited (Stelco), the largest steel producer in Canada, continued with its Greenfield steel complex at Nanticoke, Ontario on Lake Erie during 1976. The project, which has been greatly affected by inflation, accounted for nearly 80 per cent of Stelco's capital investments in 1976. During 1976 construction was actively underway on many segments of the complex, particularly the ironmaking and steelmaking facilities and the 1 200-metre dock. The cost of Phase 1, which has been expanded from its earliest concept is now estimated at $1.2 billion, nearly 3 times the original figure. Initial capacity will be 1.2 million tonnes, with start-up scheduled for April 1980. Eventual capacity at Nanticoke is expected to be 5.4 million tonnes. Initially, steel will be cast into slabs at Nanticoke and then transported to Hamilton for rolling into various steel products.

Stelco's new SL-RN direct-reduction kiln at the Griffith Mine at Bruce Lake in northwestern Ontario continued to experience operating difficulties in 1976. The kiln was shut down in September for design modifications and removal of accretions. It was scheduled to resume operations in early 1977.

The Algoma Steel Corporation, Limited is in the final stages of a major investment program that has raised its steelmaking capacity from under 2.7 million tonnes to 3.9 million tonnes annually. However, during 1976 the company experienced several major operating problems at the steelworks. The new No. 7 blast furnace and new No. 9 coke battery, both installed in 1975, had major technical difficulties. The problem with the blast furnace was successfully resolved but the coke battery will need to be rebuilt. These operating problems, combined with poor demand for structural steel products, produced a pre-tax financial loss for Algoma for 1976.

Table 5. Disposition of rolled-steel products[1], 1975-76

	1975	1976[p]	% Growth
		(tonnes)	
Wholesalers, warehouses and steel service centres	1 349 794	1 217 397	− 9.8
Automotive and aircraft	1 149 448	1 540 514	+34.0
Agricultural	218 375	231 812	+ 6.2
Contractors — building	559 982	522 832	− 6.6
Construction — public and utility	45 179	38 646	−14.5
Structural steel fabricators	897 686	711 720	−20.7
Containers	463 514	514 962	+11.1
Machinery and tools	306 065	309 475	+ 1.1
Wire, wire products and fasteners	617 207	687 894	+11.5
Natural resources and extractive industries	236 747	217 449	− 8.2
Appliances and utensils	163 512	179 171	+ 9.6
Other metal stamping and pressing	637 487	634 949	− 0.4
Railway operating	307 914	318 478	+ 3.4
Railroad cars and locomotives	154 110	85 025	−44.8
Shipbuilding	58 754	19 114	−67.5
Pipes and tubes	1 470 130	1 223 031	−16.8
Miscellaneous	65 241	74 670	+14.5
Total domestic shipments	8 701 145	8 527 139	− 2.0
Producer exports[2]	780 838	1 293 589	+65.7
Total producer shipments	9 481 983	9 820 728	+ 3.7

Sources: Statistics Canada; *Primary Iron and Steel* (monthly).
[1]Includes ingots and semis, but excludes steel castings, pipe and wire. [2]Total rolled-steel exports amounted to 0.883 4 and 1.432 3 million tonnes in 1975 and 1976 respectively.
[p]Preliminary.

Review table 12 or 6

Table 6. Canada, trade in steel by product[1], 1974-76

	Imports			Exports		
	1974	1975	1976[p]	1974	1975	1976[p]
	(000 tonnes)					
1. Steel castings (including grinding balls)	14.3	17.1	13.4	24.4	26.8	22.7
2. Ingots	7.5	60.7	10.4	20.7	1.1	36.0
3. Semi-finished steel blooms, billets, slabs	40.3	45.9	12.0	228.0	34.1	94.0
4. Total (1+2+3)	62.1	123.7	35.8	273.1	62.0	152.7
5. Finished steel						
A) Hot-rolled						
Rails	27.8	56.2	18.8	130.0	125.9	162.1
Wire rods	295.8	236.6	157.3	128.2	86.2	165.4
Structurals	594.2	190.7	242.4	113.0	90.1	131.8
Bars	446.4	123.6	134.2	66.8	39.2	43.0
Track material	6.7	11.3	5.4	7.5	2.3	3.6
Plate	545.7	346.2	214.7	175.3	154.0	165.5
Sheet and strip	450.9	96.8	68.8	141.4	141.7	317.3
Total hot-rolled	2 367.5	1 061.4	841.6	762.2	639.4	988.7
B) Cold-rolled						
Bars	32.5	22.7	14.1	15.9	7.3	6.6
Sheet and strip	132.2	36.9	40.6	31.6	23.5	84.8
Galvanized	56.9	17.2	48.8	70.6	58.7	106.4
Other[1]	137.5	85.5	94.3	194.4	119.3	115.8
Total cold-rolled	359.1	162.3	197.8	312.5	208.8	313.6
6. Total finished steel (A+B)	2 726.6	1 223.7	1 039.4	1 074.7	848.2	1 302.3
7. Total rolled steel (2+3+6)	2 774.4	1 330.3	1 061.8	1 323.4	883.4	1 432.3
8. Total steel (4+6)	2 788.7	1 347.4	1 075.2	1 347.8	910.2	1 455.0
9. Total steel (raw steel equivalent)[2]	3 603.1	1 712.9	1 385.7	1 668.8	1 163.6	1 844.0
10. Fabricated steel products						
Steel forgings	10.0	10.9	8.2	38.3	31.8	42.5
Pipe	250.2	196.1	169.6	350.0	325.7	280.0
Wire	109.6	80.5	77.7	61.3	42.7	45.5
11. Total fabricated	369.8	287.5	255.5	449.6	400.2	368.0
12. Total castings, rolled steel and fabricated (8+11)	3 158.5	1 634.9	1 330.7	1 797.4	1 310.4	1 823.0

Source: Statistics Canada; Exports and Imports by Commodities. *Ledger 11, Trade summaries*
[1]Includes steel for porcelain enameling, terneplate, tinplate and silicon steel sheet and strip. [2]Calculation: finished steel (row 6) divided by 0.77 plus steel castings, ingots and semis (row 4).
[p]Preliminary.

The final part of the present Algoma expansion program is the construction and installation of a two-strand continuous casting machine for the production of slabs up to 304.8 millimetres thick and from 1 016 to 2 159 millimetres wide. Output of 680 000 tonnes annually is scheduled to commence in mid-1977.

During 1976 capital and mine development expenses were reduced to $51.4 million. Two slab reheating furnaces were rebuilt and the No. 6 blast furnace relined. In 1977 the No. 5 blast furnace is to be relined and the No. 9 coke oven battery rebuilt.

Late in 1976 Algoma expressed concern about imported steel products being sold in Canada, particularly rolled structural shapes, and at year-end was preparing to file a complaint of dumping to the Anti-Dumping Tribunal.

Dominion Foundries and Steel, Limited (Dofasco) is also expanding its steelmaking and steel processing facilities at Hamilton. Net capital spending on expansion and improvements totalled $91 million in 1976. In mid-year, Dofasco brought on stream a new 5-strand 1828.8 millimetre tandem cold-rolling mill which increased the company's cold-rolling capacity to about 2 million tonnes annually.

Table 7. Canada, value of trade in steel castings, ingots, rolled and fabricated products, 1974-76.

	Imports			Exports		
	1974	1975	1976^p	1974	1975	1976^p
	($000)					
Steel castings	12 778	22 319	16 588	12 921	18 787	17 091
Steel forgings	12 277	22 261	16 339	30 942	36 234	49 076
Steel ingots	3 357	9 672	2 413	3 923	649	6 212
Rolled products						
Semis	10 919	12 603	4 503	40 914	9 858	17 833
Other	915 411	503 800	374 010	327 477	284 616	383 736
Fabricated						
Pipe and tube	150 518	183 058	130 740	146 497	208 131	151 899
Wire	68 961	65 787	58 635	35 323	26 791	29 132
Total steel	1 174 221	819 500	603 228	597 997	585 066	654 979

Source: Statistics Canada; Exports and Imports by Commodities. Note: The values in this table relate to the tonnages shown in Table 6.
^{p}Preliminary

Dofasco's new basic oxygen steelmaking plant continued under construction during 1976 and is scheduled for completion in 1978. Initially, capacity will be approximately 1 million tonnes of crude steel annually. The site has been designed so that capacity can be increased in stages to about 4 million tonnes.

Eight new soaking pits and a new crop shear are being installed to raise hot-rolled capacity to 3.4 million tonnes in 1978. The new No. 6 coke oven battery will also be completed in 1978. This plant will be capable of producing about 420 000 tonnes of coke annually.

Sidbec-Dosco Limited continued with its major expansion plans destined to make it the fourth largest steel company in Canada, and a significant force in the Canadian steel industry. As part of its Phase 2 program initiated in 1973, Sidbec-Dosco has vertically integrated into iron ore production and sponge iron production, as well as embarking on a major expansion of primary steel production to bring it in balance with existing rolling capacity. Sidbec has taken a 50.1 per cent equity in the Sidbec-Normines Inc. project at Fire Lake, Quebec to provide a long-term supply of high-quality iron ore for its direct-reduction facilities. The 6.0-million-tonne-a-year Fire Lake iron ore pellet project is expected to come on stream at the end of 1977. A second Midrex direct-reduction plant was completed in the fall of 1976, but its start-up will be delayed until April 1977, because labour strikes prevented the completion of essential winterization work on the new plant. This second Midrex plant will increase Sidbec's direct-reduced iron capacity from 400 000 tonnes a year to over 1 million tonnes. The direct-reduced iron surplus to Sidbec's requirements will be sold on the open market. Sidbec-Dosco is also nearing completion of the installation of two 136-tonne electric furnaces and two continuous-casting machines, one for billets and one for slabs. These facilities are expected to be completed by mid-1977 and will increase Sidbec's annual steelmaking capacity from 635 000 tonnes to 1.5 million tonnes.

Table 8. Canada, trade in steel[1] by country, 1974-76

	Imports			Exports		
	1974	1975	1976^p	1974	1975	1976^p
	(000 tonnes)					
United States	1 490.5	685.9	482.5	1 331.1	942.9	1 219.0
Britain	165.0	131.1	113.8	30.1	26.8	58.7
ECSC[2] countries	531.2	370.2	138.9	80.5	33.0	237.7
Japan	792.5	330.3	433.9	0.0	0.2	0.3
Other	179.3	117.4	161.6	355.7	307.5	307.3
Total	3 158.5	1 634.9	1 330.7	1 797.4	1 310.4	1 823.0

Source: Statistics Canada; Exports and Imports by Commodities (monthly).
[1]Comprised of steel castings, ingots, semis, finished steel, forgings, pipe and wire. [2]European Coal and Steel Community
^{p}Preliminary.

Table 9. Canadian crude steel supply and demand, 1965, 1970, 1974-76

	Crude steel production	Imports[1]		Exports[1]		Indicated consumption[2]	
		A[3]	B[4]	A[3]	B[4]	A	B
	(000 tonnes)						
1965	9 134	2 238	2 624	990	1 120	10 382	10 638
1970	11 200	1 524	1 986	1 696	2 086	11 028	11 100
1974	13 623	3 603	4 191	1 669	2 306	15 557	15 508
1975	13 025	1 713	2 139	1 164	1 727	13 574	13 437
1976[p]	13 136	1 386	1 762	1 844	2 380	12 678	12 518

Source: Statistics Canada.
[1]Trade of Canada, adjusted to equivalent crude steel by Mineral Development Sector. [2]Production plus imports, less exports, with no account taken for stocks. The two columns of figures depend on the two sets of values for trade. [3]Calculations: total finished steel (all hot- and cold-rolled steel, but excluding wire, steel, pipe and tube) divided by 0.77, plus steel castings, ingots and semis. See Table 6. [4]Calculations: total hot- and cold-rolled steel, steel forgings, wire, and steel pipe and tube divided by 0.75, plus steel castings, piston ring castings, ingots, semis and ingot moulds and stools.
[p]Preliminary.

Interprovincial Steel and Pipe Corporation Ltd. (Ipsco) of Regina, the largest steel and pipe producer in Canada, with capacity of about 500 000 tonnes a year, carried out investigations relative to an expansion of capacity in 1976. The motivating factor is the potential market for Arctic-grade large-diameter pipe to be used in any northern pipeline to transport natural gas. During the year, Ipsco carried out a 5-mile test order based on specifications required in the Alcan-Foothills system. Late in the year Ipsco acquired Brookes Tube Ltd., a small-diameter pipe producer in Alberta.

Sydney Steel Corporation in Sydney, Nova Scotia, continued to encounter difficulties with production and markets in 1976. The provincial Crown Corporation is investigating a rehabilitation program which includes the transformation of two open-hearth furnaces into two Q-BOP furnaces and the installation of a second casting machine.

The Atlas Steels Division of Rio Algom Limited, Canada's largest producer of stainless and specialty steels, continued with its major program of conversion and expansion of its steel-producing operations. At its Welland, Ontario location a new melt shop is being built to include two 54-tonne and one 23-tonne electric arc furnaces, and a vacuum-refining system for stainless steels. Completion is expected by mid-1977. In late 1976 the 23 tonne and one of the two 54-tonne furnaces were in operation. Also at Welland, a new Sendzimir cold-rolling mill was commissioned in the fall of 1976. At Tracy, Quebec a vacuum decarbonizing facility for the treatment of stainless steels became operational in late 1976. Earlier in the year the Tracy plant experienced a 9-week strike.

Most of the other regional steel producers had projects under way during the year to either increase efficiency or to raise capacity. The Manitoba Rolling Mills Division of Dominion Bridge Company, Limited (owned 43.5 per cent by Algoma) at Selkirk, Manitoba commissioned a new merchant bar rolling mill. The $30-million mill replaced two older, smaller mills. Western Canada Steel Limited commissioned a new 73-tonne 5.5-metre-diameter electric arc furnace to replace the existing 27-tonne electric arc furnace. This will increase Western Canada's steelmaking capacity from 99 800 tonnes to 181 400 tonnes. Burlington Steel Division of Slater Steel Industries Limited completed renovation of its grinding ball shop during 1976.

A concept which has been receiving attention in Canada recently has been the establishment of tidewater, export-oriented, semi-finished steel plants with equity participation by both domestic and foreign steel companies. The most advanced concept has been initiated by Cansteel Corporation, a Crown corporation of the Nova Scotia government, which along with two European steel companies, ESTEL NV Hoesch-Hoogovens and Thyssen International; National Steel Corporation of the United States and Dofasco, is conducting a feasibility study of the establishment of a 2.5-million-tonne-a-year "semis" plant at Gabarus Bay, Cape Breton Island, Nova Scotia. On the west coast of Canada, a preliminary feasibility study was completed by Nippon Kokan Kaisha, a major Japanese steel producer, and the government of British Columbia on the establishement of a 4-million-tonne-a-year "semis" plant. It was announced in November 1976 that both parties had reached agreement to cease, indefinitely, any further study. The reasons given were the depressed market for steel products, problems involving site location, and financing.

Prices

Steel prices increased during the year in the range of 4 to 10 per cent, reflecting increasing cost of production. These prices were in line with the Anti-Inflation Board (AIB) regulations. Typical increases were hot-rolled sheet (9.2 per cent), hot-rolled skelp (8.6 per cent),

Table 10. World raw steel production, 1975-76

	1975	1976[p]
	(million tonnes)	
U.S.S.R.	141.3	147.0
United States	105.8	116.1
Japan	102.3	107.4
West Germany	40.4	42.4
China	26.5	26.0
Italy	21.9	23.4
France	21.5	23.2
United Kingdom	19.8	22.7
Belgium and Luxembourg	16.2	16.7
Poland	15.0	15.9
Czechoslovakia	14.3	14.7
Canada	13.0	13.1
Spain	11.1	11.0
Rumania	9.6	10.5
India	8.0	9.4
Brazil	8.4	9.2
Australia	7.9	7.8
South Africa	6.8	7.1
East Germany	6.5	6.6
Mexico	5.3	5.3
Netherlands	4.8	5.2
Sweden	5.6	5.1
Austria	4.1	4.5
Hungary	3.7	3.8
South Korea	2.0	3.5
North Korea	2.9	3.0
Yugoslavia	2.9	2.7
Bulgaria	2.3	2.5
Argentina	2.2	2.4
Turkey	1.7	1.9
Finland	1.6	1.7
Taiwan	1.0	1.6
Others	9.5	9.8
Total	645.9	683.2

Source: American Iron and Steel Institute.
[p] Preliminary.

cold-rolled sheet (9.2 per cent), galvanized sheet (7.7 per cent), tinplate (3.8-4.5 per cent), plate (9.2-10.3 per cent), and structurals (4.6 per cent). This resulted in some typical selling prices per tonne by year-end of $275 for hot-rolled sheet, $335 for cold-rolled sheet, $295 for plate, $280 for large structurals, and a starting base of about $340 for galvanized sheet.

Raw material prices increased during the year, but significantly less than the increases experienced in the 1973-75 period. Coking coal was in good supply and, indeed, was in excess of market demand. Consequently, spot prices declined but long-term prices remained firm, with slight increases due to annual contract escalation costs. Iron ore prices increased, as the Lake Erie Base Price registered a 12.5 per cent increase in 1976, largely in response to increased production costs. Scrap prices in 1976 exhibited some volatility with the composite price for No. 1 heavy melting steel in the United States starting at a low price of $68 per tonne in early 1976, rising dramatically to $94 in May followed by a sharp decline to about $60 in December. Prices for oil and natural gas continued to increase in 1976, mainly due to the pricing policies of the federal and provincial governments relative to these two fuels.

World review

There were some positive signs early in 1976 that the steel industries of most market-economy countries were beginning to recover from the poor year of 1975 as steel shipments increased. However, the year resulted in only moderate growth overall. Many consumers built up stocks early in the year and then ran them down in the later months. Consequently, shipments by steel mills were declining at the end of the year. Many steel markets remained depressed, particularly for heavy construction and building materials, reflecting lagging investment. Only the automobile industry stood out in most countries.

Total world steel production increased by roughly 5 per cent in 1976 to some 683.2 million tonnes, even though capacity utilization in many countries was less than 75 per cent. The increase by region was approximately 8.6 million tonnes in Western Europe, 6.3 million tonnes in Eastern Europe, 10.5 million tonnes in North America, 0.8 million tonnes in Latin America, 0.4 million tonnes in Africa and 3.2 million tonnes in the Far East.

Table 11. Capital expenditures of selected Canadian companies in 1976 and plans for 1977

	Estimated for 1976	Planned for 1977	Percentage change
	($ million)		
Manufacturing	2 916	3 413	+17.0
Mining	891	1 269	+42.4
Oil and gas companies	2 617	3 382	+29.2
Oil and gas pipelines	436	455	+ 4.4
Transportation and storage	807	936	+16.0
Communications	1 784	1 937	+ 8.6
Electric utilities	4 242	5 612	+32.3
Other companies	834	982	+17.7
Total	14 527	17 986	+23.8

Source: Department of Industry, Trade and Commerce, Canada.

With the sluggish demand for steel prevalent in many domestic markets, firms attempted to maintain levels of production and employment by increasing exports. This was evident, particularly, by export-orientated countries. Many of these exports were low-priced and made inroads in many markets to the detriment of domestic steel producers. Consequently this situation led to a series of protectionist measures to protect domestic industries. The United States reacted to protect its stainless steel industry when the U.S. International Trade Commission ruled that imports were causing unprecedented hardship to the domestic industry and requested quotas lasting five years, or until the domestic industry recovered from high unemployment and depressed operating levels. Low-priced imports from Japan and Western Europe were the prime target for quotas. The United States successfully negotiated an "orderly marketing agreement" (OMA) with Japan, but other countries refused to agree to such an arrangement. The outcome was the imposition of quotas on stainless steel imports on all countries in June 1976.

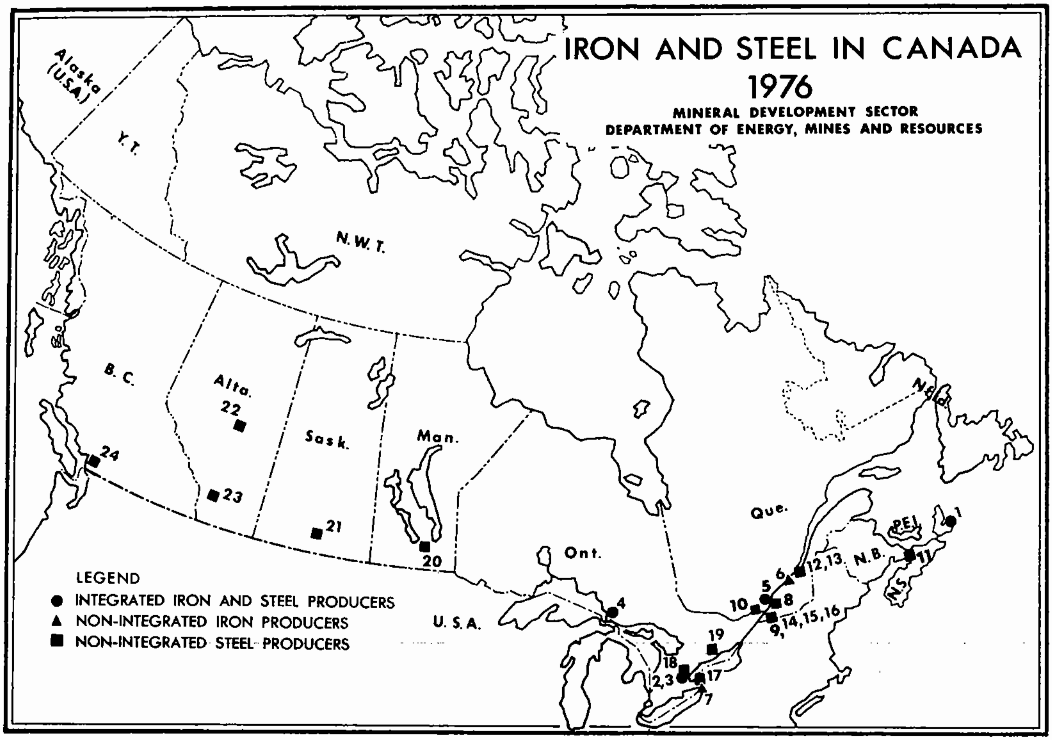
In Europe, when optimism for the second half of the year failed to materialize there was increasing concern in the European Economic Community (EEC) regarding the untenable levels of Japanese imports. A gentleman's agreement had been successfully negotiated in late 1975 between the EEC and the Ministry of International Trade and Industry (MITI), representing the six largest Japanese steel producers, on the level of Japanese exports to the EEC in 1976. By late 1976, however, it was apparent that Japanese steel exports to the EEC were running at more than 50 per cent in excess of agreed levels, and the EEC was attempting to reach a broader agreement with the Japanese. The EEC claimed that smaller Japanese steel producers excluded by the agreement were partially responsible, but also that the large companies had found ways around the agreement, possibly by diverting steel to countries around the edge of the EEC and re-exporting the steel into the EEC. To strengthen further their position, the EEC steel producers also agreed at the end of 1976 to establish a steel cartel called "Eurofer". Eurofer would control production targets to match actual supply and demand, as well as fixing minimum prices to arrest the depression of the market by cheap imports.

The American Iron & Steel Institute became alarmed by increasing protectionist moves in the EEC, and in October took up the issue with United States government trade representatives, claiming that a Japanese-EEC conspiracy was leading to a marked increase in Japanese exports to the United States. In both the United States and Canada late in the year many firms were voicing opinions that steel products were being "dumped" in their domestic markets. In December, Great Britain imposed a provincial anti-dumping ban on reinforcing bars from South Africa. Thus, the world steel industry in the market economies ended the year with the pessimistic prospect of increasing protectionism in steel trade to combat domestic problems of unemployment and under-utilization of capacity.

Table 12. Canada, rolled steel supply and demand, 1973-76

	Producer or mill shipments[1]	Exports[2]	Imports[3]	Apparent rolled steel consumption[4]	Raw steel production[5]
			(million tonnes)		
1973	9.921	1.235	1.815	10.501	13.386
1974	10.377	1.323	2.774	11.828	13.623
1975	9.482	0.884	1.330	9.928	13.025
1976[p]	9.821	1.432	1.062	9.451	13.136
% change					
1976/75	+3.6	+62.0	−20.2	−4.8	+0.9

Sources: Statistics Canada; *Primary Iron and Steel* (monthly) and *Trade of Canada*.
[1]Comprises domestic shipments plus producer exports. A portion of domestic shipments to warehouses and steel service centres is also exported. Excludes steel castings amounting to 174 000 tonnes in 1973, 189 000 tonnes in 1974, 195 000 tonnes in 1975, and 157 000 tonnes in 1976. [2]Total exports includes producer exports, plus exports from warehouses and steel service centres. Excludes exports of pipe, wire, forgings and steel castings. [3]Excludes imports of pipe, wire, forgings and steel castings. [4]Excludes apparent consumption of steel castings. [5]Includes production of steel castings amounting to 187 024 tonnes in 1973, 201 248 tonnes in 1974, 217 101 tonnes in 1975 and 166 526 tonnes in 1976.
[p]Preliminary.



Integrated iron and steel producers
(numbers refer to locations on map above)

1. Sydney Steel Corporation (Sydney)
2. Dominion Foundries and Steel, Limited (Hamilton)
3. The Steel Company of Canada, Limited (Hamilton)
4. The Algoma Steel Corporation, Limited (Sault Ste. Marie)
5. Sidbec-Dosco Limited (Contrecoeur)

Nonintegrated iron producers

6. Quebec Iron and Titanium Corporation (Sorel)
7. Canadian Furnace Division of Algoma (Port Colborne)

Principal nonintegrated steel producers

8. The Steel Company of Canada, Limited (Contrecoeur)
9. QSP Ltd. (Montreal)
10. Ivaco Industries Limited (L'Orignal, Ontario)
11. Enheat Limited (Amherst)
12. Atlas Steels Division of Rio Algom Limited (Tracy)
13. Colt Industries (Canada) Ltd. (Sorel)
14. Canadian Steel Foundries Division of Hawker Siddeley Canada Ltd. (Montreal)
15. Canadian Steel Wheel Limited (Montreal)
16. Sidbec-Dosco Limited (Montreal)
17. Atlas Steels (Welland)
18. Burlington Steel Division of Slater Steel Industries Limited (Hamilton)
19. Lake Ontario Steel Company Limited (Whitby)
20. Manitoba Rolling Mills Division of Dominion Bridge Company, Limited (Selkirk)
21. Interprovincial Steel and Pipe Corporation Ltd. (Regina)
22. Premier Works of Stelco (Edmonton)
23. Western Canada Steel Limited (Calgary)
24. Western Canada Steel Limited (Vancouver)

Lead

G.R. PEELING

In 1976 Canada's production of lead, based on lead produced from domestic materials and the recoverable content of ores and concentrates exported, was 259 000 tonnes*, a decrease of 25.8 per cent from the 1975 level. The value of production was also down but not in proportion to the lower tonnage produced because of the increasing value realized for lead during the year. The value declined from $156.0 million in 1975 to $129.4 million in 1976. Mine output of lead, expressed as the lead content of domestic ores and concentrates produced, was estimated at 247 082 tonnes, a decline of 29.9 per cent from the 352 502 tonnes produced in 1975. This was the lowest level of production recorded in 12 years and was mainly a result of prolonged strikes at several major producers during the year.

Primary refined lead output totalled 175 720 tonnes, up 2.5 per cent from the 1975 level of 171 516 tonnes. This is the second straight year of increased output, but the level is still substantially below the 186 890 tonnes produced in 1973. Capacity utilization in the industry was about 80 per cent during 1976.

Export of lead contained in ores and concentrates decreased to 140 933 tonnes in 1976 from 211 909 tonnes in 1975. There was a significant drop in exports to Japan, Germany, Brazil and the United States, with only exports of ores and concentrates to Belgium and Luxembourg showing a significant gain. Metal exports in 1976 totalled 118 887 tonnes, up from the 115 994 tonnes exported in 1975. The United States and the United Kingdom continued as Canada's two most important metal export markets, accounting for about 67 per cent of total exports. Imports of refined metal were 3 664 tonnes compared with 3 436 tonnes in 1975.

Canadian consumption of primary and secondary lead metal in 1976 was estimated at 63 000 tonnes and 35 000 tonnes respectively, compared to 54 410 tonnes and 34 782 tonnes in 1975. Since preliminary statistics for 1976 consumption are not available, Table 1 shows 1974 and 1975 statistics for comparative purposes.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Canadian developments

Canadian lead production in 1976 continued to be adversely affected by the depressed economic conditions in the major industrial economies. Although metal production increased moderately in Canada in 1976, mine production of lead was at a 12-year low as strikes and technical problems reduced production at several major mines. Nonetheless, relative to other base metal industries, the lead industry enjoyed better economic conditions in 1976. As mine producers adjusted production downwards to keep pace with the prevailing market conditions for zinc and copper, the output of co-product and by-product lead (over 95 per cent of Canadian production falls in this category), was resultantly kept low.

Mine production

Newfoundland. ASARCO Incorporated operates the Buchans mine in central Newfoundland, the only lead producer in the province. Output of lead in concentrates in 1976 was down slightly from 1975 (Table 3) but production in all forms, as indicated in Table 1, shows a substantial increase because of inventory changes. Mill recovery** of lead has remained unchanged during the last two years at 85 per cent. A new 25-year agreement (replacing a 1928 agreement) was signed in 1976 between ASARCO and The Price Company Limited covering the joint venture mining operations at Buchans. The old 50-50 agreement has been replaced by a 51 per cent Price, 49 per cent ASARCO agreement with the latter continuing to act as manager of the property and the former assuming management of joint venture exploration projects. Present ore reserves at Buchans are sufficient to support the existing operation through 1979.

New Brunswick. Output from the mining division of Brunswick Mining and Smelting Corporation Limited

**The term "mill recovery" refers to lead recovered only in the lead concentrate.

was down 32 per cent from the 1975 level because of a three-month strike. Although the strike was settled on August 28, production did not return to pre-strike levels until late in the year. Production of lead in concentrate dropped from 54 149 tonnes in 1975 to 36 884 tonnes in 1976. Mill recoveries for lead declined from 59 to 57 per cent in 1976. The company operates two mines, the No. 12 and No. 6, which supply feed to a central concentrator located at the No. 12 mine, with a capacity of 9900 tonnes of ore a day. The zinc and copper concentrates are sold to custom smelters and the lead concentrates are railed 72 kilometres to the company's lead plant at Belledune. The expansion program at the No. 12 mine, at an expected total cost of $53 million, will increase hoisting capacity from 6800 to 9900 tonnes a day. A new production shaft is presently being sunk and is expected to be operational by 1979. Open-pit mining at the No. 6 mine is scheduled to end in 1977 but a 1200-metre ramp has been driven to an ore zone beneath the open pit. Mining at a rate of 900

Table 1. Canada, lead production, trade and consumption, 1975-76

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Production				
All forms[1]				
British Columbia	70 612	31 545 448	89 000	44 264 000
New Brunswick	59 092	26 399 284	62 000	30 808 000
Northwest Territories	83 391	37 254 292	54 000	26 808 000
Yukon	122 864	54 888 680	38 000	19 104 000
Newfoundland	5 219	2 331 396	9 000	4 621 000
Ontario	6 192	2 766 329	6 000	3 186 000
Quebec	1 644	734 569	1 000	460 000
Manitoba	119	53 117	. . .	137 000
Total	349 133	155 973 115	259 000	129 388 000
Mine output[2]	352 502		247 082	
Refined production[3]	171 516		175 720	
Exports				
Lead contained in ores and concentrates				
Japan	120 793	32 348 000	75 123	17 952 000
United States	38 368	9 729 000	27 900	6 746 000
Brazil	15 778	3 821 000	11 165	2 412 000
Belgium and Luxembourg	8 613	1 893 000	15 174	2 357 000
West Germany	23 875	4 963 000	9 625	1 442 000
United Kingdom	2 217	486 000	1 946	365 000
Italy	2 265	403 000	—	—
Total	211 909	53 643 000	140 933	31 274 000
Lead, pigs, blocks and shot				
United States	23 173	11 051 000	38 337	17 688 000
United Kingdom	44 306	17 751 000	36 997	14 549 000
People's Republic of China	14 498	5 901 000	8 347	3 735 000
Italy	6 952	3 103 000	5 973	2 399 000
India	2 121	878 000	4 713	2 148 000
Netherlands	2 714	941 000	5 071	1 931 000
Japan	—	—	2 134	818 000
Spain	—	—	1 602	740 000
Pakistan	1 832	771 000	1 425	659 000
Sweden	592	197 000	1 173	487 000
Other	13 759	5 028 000	8 630	3 126 000
Total	109 947	45 621 000	114 402	48 280 000

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Lead and alloy scrap (gross weight)				
South Africa	3 605	607 000	6 843	1 446 000
West Germany	35	16 000	3 788	971 000
United States	1 691	349 000	1 234	404 000
Belgium and Luxembourg	225	116 000	539	296 000
Denmark	233	112 000	618	133 000
South Korea	247	40 000	665	124 000
Netherlands	558	137 000	275	57 000
Japan	–	–	375	55 000
Other	5 267	1 026 000	572	127 000
Total	11 861	2 403 000	14 909	3 613 000
Lead fabricated materials not elsewhere specified				
United States	5 606	3 691 000	4 436	2 553 000
Sweden	–	–	18	14 000
Puerto Rico	–	–	19	12 000
Australia	–	–	10	7 000
Other	441	203 000	2	1 000
Total	6 047	3 894 000	4 485	2 587 000
Imports				
Lead pigs, blocks and shot	1 962	925 000	1 941	928 000
Lead oxide; litharge, red lead, mineral orange	1 002	650 000	386	311 000
Lead fabricated materials not elsewhere specified	472	574 000	1 337	1 114 000
Total	3 436	2 149 000	3 664	2 353 000

(table continued on next page)

Table 1. (concl'd)

	1974r			1975		
	Primary	Secondary[4]	Total	Primary	Secondary[4]	Total
	(tonnes)					
Consumption						
Lead used for, or in the production of:						
antimonial lead	1 175	13 778	14 953	1 101	12 242	13 343
battery and battery oxides	26 207	4 914	31 121	18 908	1 820	20 728
cable covering	2 836	586	3 422	3 312	535	3 847
chemical uses; white lead, red lead, litharge, tetraethyl lead, etc.	20 885	x	20 885	19 190	x	19 190
copper alloys; brass, bronze, etc.	379	81	460	148	56	204
lead alloys: solders	4 314	3 577	7 891	2 198	5 077	7 275
others (including babbitt, type metals, etc.)	1 418	1 476	2 894	1 122	1 577	2 699
semifinished products; pipe sheet, traps, bends, blocks for caulking, ammunition, etc.	4 884	329	5 213	4 278	808	5 086
Other	3 106	9 789	12 895	4 153	12 667	16 820
Total, all categories	65 204	34 530	99 734	54 410	34 782	89 192

Source: Statistics Canada.
[1]Lead content of base bullion produced from domestic primary materials (concentrates, slags, residues, etc.) plus estimated recoverable lead in domestic ores and concentrates exported. [2]Lead content of domestic ores and concentrates produced. [3]Primary refined lead from all sources. [4]Includes all remelt scrap lead and scrap lead used to make antimonial lead.
r Revised; p Preliminary; — Nil; . . . Less than 1000 tonnes; x confidential, but included in "other".

tonnes a day is scheduled to commence in early 1977 and continue for about four years, at which time reserves are expected to be depleted. Although ore output may increase only slightly after the expansion at the No. 12 (because of the phase-out of the No. 6 mine), metal output is expected to increase about 30 per cent because of higher grades at the No. 12 mine. Reserves at the No. 6 mine were listed as 1 439 000 tonnes grading 6.99 per cent zinc, 2.53 per cent lead, 0.31 per cent copper and 76.8 grams of silver a tonne, and reserves at the No. 12 as 95 158 000 tonnes grading 9.21 per cent zinc, 3.77 per cent lead, 0.32 per cent copper and 96.3 grams of silver a tonne. There is also a substantial copper-rich zone at the No. 12 mine, containing 8 594 000 tonnes grading 1.13 per cent zinc, 0.40 per cent lead, 1.11 per cent copper and 29.1 grams of silver a tonne.

Heath Steele Mines Limited was one of the few lead producers to show an increase in production in 1976. The production of lead in concentrates increased from 9393 tonnes in 1975 to 13 263 tonnes in 1976 as a result of an increase in tonnage of ore milled, grade of ore treated and recoveries in the mill (up from 49 to 55 per cent). Reserves at year-end 1976 were listed as 28 850 000 tonnes grading 1.16 per cent copper, 1.52 per cent lead, 4.40 per cent zinc, and 61.4 grams of silver a tonne.

Nigadoo River Mines Limited, a subsidiary of the Quebec-based Sullivan Mining Group Ltd., operates the Little Chief Mine near Bathurst. Production decreased to 4185 tonnes of lead in concentrates in 1976 compared with 5160 tonnes in 1975. Recoveries in the mill increased from 67 to 87 per cent but a decrease in ore grade and amount of mill throughput accounted for the lower production. Reserves at year-end 1976 were listed as 226 680 tonnes grading 3.24 per cent lead, 2.92 per cent zinc, 0.16 per cent copper and 11.9 grams of silver a tonne. These reserves are sufficient to sustain the operation until the first quarter of 1978 at the present operating level.

Quebec. All lead production in Quebec is a byproduct of copper and zinc mining and because of the prevailing poor markets for these two metals production of lead was down for the second year in succession.

The depressed copper price and operating difficulties forced the Sullivan Mining Group Ltd. to announce at the annual meeting that operations at the Cupra and D'Estrie mines in the Eastern Townships would cease on January 31, 1977. Although mainly copper and zinc producers, the two mines produced about 500 tonnes of lead contained in concentrates in 1976.

The only other producer of lead in Quebec, the Golden Manitou mine of Manitou-Barvue Mines Limited, changed ownership during the year when Louvem Mining Company Inc. purchased the property and mill. Louvem's share of the lead output was 148 tonnes in 1976; Manitou-Barvue's share was 373 tonnes.

Ontario. All lead production in Ontario, as in Quebec, is a byproduct of copper-zinc production and was down for the second year in succession. One operator announced that closure would occur in 1977.

Difficulties in treating certain ore types at the Sturgeon Lake joint venture operated by Falconbridge Copper Limited affected metal recoveries unfavourably during the year and milling problems associated with oxidized and altered ore near fault zones continued. During August a new lead circuit, built at a cost of $456,000, started operating on feed from current milling and stocks of low-grade lead concentrates. Production of lead in concentrate in 1976 was 548 tonnes, up from the 253 tonnes produced in 1975. Lead recoveries in the mill improved to 12 per cent in 1976 (up from 4 per cent the previous year) and research is continuing on the treatment of the refractory ores to improve the recovery rate. Reserves at the Sturgeon Lake mine were 1 240 000 tonnes grading 3.01 per cent copper, 9.06 per cent zinc, 1.10 per cent lead, 0.7 gram gold and 169.6 grams of silver a tonne at year-end.

Operations at Mattabi Mines Limited, also in the Sturgeon Lake area of northern Ontario, were at capacity in 1976. Treatment of higher-grade ore and slightly improved recovery rates in the mill resulted in an increase in lead in concentrate production during 1976. The mill recovery rate for lead improved marginally to 28 per cent in 1976. Ore reserves as of December 31 were 5.9 million tonnes grading 6.89 per cent zinc, 0.79 per cent copper, 0.68 per cent lead and 91.5 grams of silver a tonne.

Output of lead from the Geco mine of Noranda Mines Limited was down in 1976 as production was tailored to market conditions for copper and zinc. Lead in concentrate production dropped from 1659 tonnes in 1975 to 1515 tonnes in 1976. Operations continued to be hampered by a shortage of skilled miners. The addition of an on-stream analysis system for improving metal recoveries in the mill proved beneficial during the year as lead recovery improved from 28 to 43 per cent in 1976. Reserves, as of year-end 1976, were 24.9 million tonnes grading 1.87 per cent copper, 3.59 per cent zinc, about 0.15 per cent lead, and 5.11 grams of silver a tonne.

Operations were normal at the Kidd Creek mine of Texasgulf Canada Ltd. near Timmins. Lead in concentrate production decreased from 5932 tonnes in 1975 to 4649 tonnes in 1976. Lead metal recovery declined from 45 to 43 per cent during the year. At year-end, ore reserves above the 850-metre level were 80.7 million tonnes grading 2.73 per cent copper, 0.22 per cent lead, 6.8 per cent zinc and 79 grams of silver a tonne. Mining from the open pit will cease in 1977, after which all output will come from underground. Work on the $100-million expansion program continued and mining capacity will be 4.5 million tonnes of ore annually by 1979. When the program is completed with the addition of the second shaft, lead output is expected to increase from the existing 4000-tonne level to about 7000 tonnes a year.

Willroy Mines Limited announced that operations at the Manitouwadge division would cease in the first quarter of 1977 because of the completion of the open-pit mining of the Big Nama Creek crown pillar. Operations based solely on feed from the Willecho mine are

Table 2. Canada, lead production, trade and consumption, 1965, 1970, 1974-76

	Production		Exports				
	All forms[1]	Refined[2]	In ores and Concentrates	Refined	Total	Imports Refined[3]	Consumption[4]
			254·10	453·09 (tonnes)		453·09	
1965	264 723	169 175	97 036	117 086	214 122	64	81 799
1970	353 063	185 637	150 513	138 637	289 150	1 995	84 765
1974	294 268	126 460	194 089	76 027	270 116	11 357	99 734[r]
1975	349 133	171 516	211 909	109 947	321 856	1 962	89 192
1976[p]	259 083	175 720	140 933	114 402	255 335	1 941	98 000[e]

Source: Statistics Canada.
[1]Lead content of base bullion produced from domestic primary materials (concentrates, slags, residues, etc.) plus the estimated recoverable lead in domestic ores and concentrates exported; [2]Primary refined lead from all sources; [3]Lead in pigs and blocks; [4]Consumption of lead, primary and secondary in origin.
[p]Preliminary. [r]Revised; [e]Estimated.

uneconomic. Production of lead in 1976 declined to 237 tonnes from 398 tonnes in 1975. Ore reserves as of December 31, 1976 were 688 960 tonnes grading 0.28 per cent copper, 4.42 per cent zinc, and 50.4 grams of silver a tonne. The mine employed 29 staff and 149 hourly-paid workers during 1976. The lead recovery rate in the mill declined sharply in 1976 to a level of 49 per cent compared with 61 per cent in 1975.

Manitoba and Saskatchewan. A small amount of lead was produced from the mining operations of Hudson Bay Mining and Smelting Co., Limited. Hudson Bay operated nine ore sources in the Flin Flon-Snow Lake area in 1976, only two of which report lead production – Ghost Lake and Chisel Lake. Production in 1976 was 315 tonnes compared with 145 tonnes in 1975. Ore reserves at year-end were 15.9 million tonnes grading 2.9 per cent zinc, 2.66 per cent copper, 0.2 per cent lead, 1.2 grams of gold and 18.9 grams of silver a tonne.

British Columbia. Operations at the Sullivan and H.B. mines of Cominco Ltd. were normal during 1976. Output of lead increased at both mines as a result of mining higher-grade ore and improved recoveries in the mills. Production of 77 302 tonnes of lead at the Sullivan mine was almost 10 000 tonnes above the 1975 level and mill recovery of lead increased by 10 percentage points to 81 per cent in 1976. Mill recovery of lead also increased by 10 percentage points to 61 per cent at the H.B. operation in 1976. Ore reserves at the two mines were 51.7 million tonnes grading 10.9 per cent combined lead-zinc at year-end.

The Ruth Vermont mine of Consolidated Columbia River Mines Ltd., operated for part of 1976. The mill operated from mid-June until the end of December 1976 and treated about 42 000 tonnes of ore. Ore reserves at year-end were 0.2 million tonnes proven and 1.0 million tonnes probable and inferred, grading 5.53 per cent zinc, 5.03 per cent lead and 100 grams of silver a tonne. The company was placed in receivership at year-end and it is not known whether the mine will re-open in the spring of 1977 as was originally planned.

Operations at two of the smaller producers in B.C. (the Silmonac mine of Kam-Kotia Mines Limited and the Beaverdell mine of Teck Corporation Limited) were slightly improved in 1976. Both mines are operated on a day-to-day basis and reserves are not given.

Northair Mines Ltd. began production at its Bradywine Falls silver-gold-lead-zinc property in May 1976. Lead output during the year was 341 tonnes and is expected to be about 1000 tonnes annually once planned operating levels are achieved.

Production at the Lynx and Myra Falls mines of Western Mines Limited on Vancouver Island was slightly improved over the 1975 level with output of lead up from 3419 tonnes to 3586 tonnes in 1976. Increased mill throughput was responsible for the improved production as mill recovery rates remained unchanged at 81 per cent for lead. Reserves, as of year-end, were 1.5 million tonnes grading 1.2 per cent copper, 1.2 per cent lead, 7.9 per cent zinc, 3.1 grams of gold and 144 grams of silver a tonne.

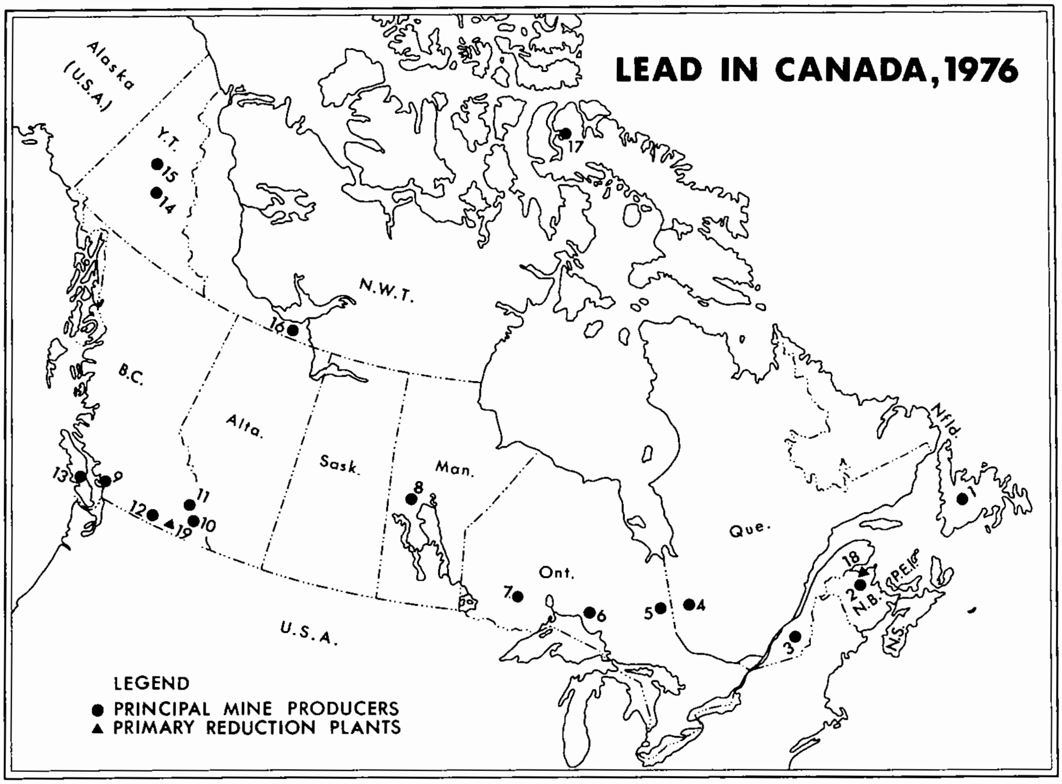
Yukon Territory. Mine output of lead in the Yukon declined dramatically in 1976 as the two producers in the Territory suffered lengthy strikes.

Cyprus Anvil Mining Corporation lost 169 production days as a result of strikes by employees at its Faro mine. The last strike, extending from July 30 until November 23, ended when mine workers agreed to a new three-year labour contract which runs until September 1978. The company was forced to declare a force majeure on shipments to its German and Japanese customers and although workers returned in November, shipments to Japan did not resume until February 1977. One of the start-up problems faced by the company was a shortage of skilled labour resulting from the strike. Early in 1977 this was still a problem and it appears that 1977 production may be slightly below normal as a carry-over from the strike. Production of lead in concentrates was 33 070 tonnes in 1976 compared with 105 380 tonnes in 1975.

United Keno Hill Mines Limited suffered a 25 per cent decline in output of lead as a result of a 42-day labour strike. The company operated four ore sources in 1976 with about 65 per cent of the mill feed coming from the Husky and Elsa mines. Production of lead in concentrates decreased from 2979 tonnes in 1975 to 2227 tonnes in 1976. Mill recovery of lead was another reason for the decline in output as it dropped 8 percentage points to 82 per cent in 1976. Ore reserves at year-end are 165 300 tonnes grading 4.6 per cent lead, 1.2 per cent zinc and 1 464 grams of silver a tonne.

Northwest Territories. Lead in concentrate production declined at Pine Point Mines Limited in 1976 because of treatment of lower-grade ore and power failures in June which closed the mill for 19 days. Increased stripping capacity will be operational in 1979 when a new 30 cubic yard walking dragline will be operative. This will lower stripping costs, which in turn will allow production from lower-grade orebodies and from deeper ore deposits on the western part of the property. Production in 1976 was 55 334 tonnes, down from 79 185 tonnes in 1975. Mill recovery of lead in the lead concentrate declined from 88 to 85 per cent.

In the high Arctic, Nanisivik Mines Ltd. commenced production at its zinc-lead-silver property on Baffin Island in October. Lead concentrate production was 434 tonnes with a lead content of 205 tonnes. Mill recovery of lead during tune-up operations was a disappointing 10 per cent in 1976, but improved significantly early in 1977. The concentrates will be exported in 1977 during the July to September shipping season. Production of lead concentrates at capacity will be about 10 000 tonnes annually.



Principal mine producers
(numbers refer to numbers on map)

1. ASARCO Incorporated
   (Buchans Unit)
2. Brunswick Mining and Smelting Corporation
   Limited (Nos. 12 & 6 mines)
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
3. Sullivan Mining Group Ltd., Cupra Division
   D'Estrie Mining Company Ltd.
4. Louvem Mining Company Inc. (Manitou-Barvue Division)
5. Texasgulf Canada Ltd.,
6. Noranda Mines Limited, Geco Division
   Willroy Mines Limited
7. Mattabi Mines Limited
   Falconbridge Copper Limited,
   Sturgeon Lake Joint Venture
8. Hudson Bay Mining and Smelting Co., Limited
   (Chisel Lake, Ghost Lake mines)
9. Northair Mines Ltd.
10. Cominco Ltd. (Sullivan and H.B. mines)
11. Kam-Kotia Mines Limited (Silmonac mine)
12. Teck Corporation Limited (Beaverdell mine)
13. Western Mines Limited
14. Cyprus Anvil Mining Corporation
15. United Keno Hill Mines Limited
16. Pine Point Mines Limited
17. Nanisivik Mines Ltd.

Primary reduction plants

18. Brunswick Mining and Smelting Corporation
    Limited, Smelting Division
19. Cominco Ltd.

Exploration and development

Nova Scotia. The test mining program on the lead-zinc property at Gays River, just north of Halifax, was completed. The property, jointly owned by Imperial Oil Limited (60 per cent) and Cuvier Mines Ltd. (40 per cent), has been explored extensively during the last three years and a decision on the feasibility of full-scale mining of the property will likely be made in 1977 once the test mining results have been fully assessed.

New Brunswick. Activity was at an all-time high during the year with much of the activity centering on the volcanic rocks of the Bathurst-Newcastle area. Discoveries made in 1975 were subjected to follow-up work in 1977. Work continued on the Restigouche and Murray Brook properties of Canex Placer Limited. The two copper zones on the Chester Mines Limited property were subject to metallurgical testing of the ore at the laboratories and mill of Nigadoo River Mines Limited in 1976. Texasgulf Inc. continued work on its Half Mile Lake property but because concentrate grades were quite low during beneficiation studies, plans to sink an 850-metre exploration shaft were deferred. Also in the Half Mile Lake area, on a project managed by Mattagami Lake Mines Limited, diamond drilling identified two sulphide zones: the first containing 0.55 million tonnes grading 1.09 per cent lead, 6.04 per cent zinc, 0.44 per cent copper and 11 grams of silver a tonne, and the second containing 0.24 million tonnes grading 0.32 per cent lead, 2.52 per cent zinc and 0.24 per cent copper. Newmont Mining Corporation of Canada Limited and The Price Company Limited optioned the Willet property in 1975 but subsequent diamond drilling of geophysical targets has so far failed to intersect any significant mineralization. Further work is planned in 1977. Sabina Industries Limited is involved in a number of joint venture projects in the province. Drilling in the Half Mile Lake area has revealed a very complex geological structure and further drilling will be undertaken in 1977; two significant sulphide zones have been identified to date but, because they remain open at depth and drilling has been widely spaced, grades are given but tonnages are not. (Zone 11 grades 6.94 per cent zinc, 1.71 per cent lead, 0.04 per cent copper and 30.5 grams of silver a tonne over a zone length of 275 metres and an assay width of 8.7 metres, and the south zone grades 3.23 per cent zinc, 0.53 per cent lead, 0.02 per cent copper and 10.6 grams of silver a tonne over a strike length of 150 metres and an assay width of 11 metres). On Sabina's Lovalls Lake property preliminary work has identified drill targets for follow-up in the 1977 season.

Ontario. The only development of note is the work on the Lyon Lake division of Mattagami Lake Mines in preparation for production in 1977. The shaft was completed in October, leaving only lateral development work, stope preparation, crusher installation and related projects still to be completed in 1977. Ore reserves are reported in Table 4.

Yukon Territory. The work on the Grum deposit is now at the feasibility study stage and a decision on the economic viability of the operation will likely be made in 1977, pending negotiations with the federal government. Expenditures by the operators of the joint venture, Kerr Addison Mines Limited (60 per cent) and Canadian Natural Resources Limited, formerly Aex Minerals Corporation, (40 per cent) have totalled about $12 million. Reserves are estimated to be 26.1 million tonnes grading 4.07 per cent lead, 6.43 per cent zinc and 62 grams of silver a tonne. About 20 million tonnes of ore are amenable to open-pit mining methods with the remainder necessitating an underground operation. Preliminary metallurgical testing suggests that zinc-lead recoveries will be about 85 per cent but final results are not yet available. Canex Placer Limited, wholly-owned subsidiary of Placer Development Limited, is continuing work on the Howard's Pass deposit and plans to construct an 80-kilometre access road to the property during 1977. Exploration activity in the Yukon now appears to be shifting to the shales as a host for lead-zinc deposits and away from the carbonates.

Northwest Territories. Exploration activity continued at a high level during 1976. Texasgulf continued surface work and diamond drilling at Izok Lake and the drill-indicated mineralization was increased to 11.0 million tonnes grading 2.8 per cent copper, 13.77 per cent zinc, 1.4 per cent lead and 70.3 grams of silver a tonne. Further diamond drilling is planned for 1977. A feasibility study on the Hackett River property of Bathurst Norsemines Ltd. and Cominco Ltd. was commissioned in 1976 but the results have not yet been released. The property has a number of deposits on it, totalling about 18 million tonnes of good-grade lead-zinc material. Cominco is also involved with Bankeno Mines Limited in the Polaris property of Arvik Mines Ltd. (75 per cent Cominco; 25 per cent Bankeno) on Little Cornwallis Island in the high Arctic. The deposit contains about 22.7 million tonnes grading 14.1 per cent zinc, 4.3 per cent lead and 34.3 grams of silver a tonne. The companies reported that during 1976 little progress was achieved in negotiations with the federal government on development of this deposit. Significant results were reported during the year for a project near the south shore of Great Slave Lake near the Pine Point Mines property. Western Mines Limited and Du Pont of Canada Exploration Limited identified a 2.54-million-tonne deposit grading 4.1 per cent lead and 11.9 per cent zinc. Further drilling is planned for 1977.

Metal production

Metal production from Canada's two primary producers increased marginally in 1976 as plants operated

(text continued on page 296)

Table 3. Principal lead mines in Canada, 1976 and (1975)

Company and Location	Mill Capacity	Grade of Ore Milled: Lead	Zinc	Copper	Silver	Ore Milled	Lead Concentrate Produced	Grade of Lead in Concentrate	Contained[1] Lead Produced	Destination[2] of Lead Concentrate
	(tonnes per day)	(%)	(%)	(%)	(g/tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Newfoundland										
ASARCO Incorporated,	1 150	6.03	10.69	0.96	105.6	188 694	16 547	58.16	10 830	1,5,7
(Buchans Unit),	(1 150)	(5.92)	(10.54)	(0.95)	(103.9)	(210 466)	(18 367)	(57.27)	(11 882)	(3,7)
Buchans										
New Brunswick										
Brunswick Mining and Smelting	8 950	2.80	7.01	0.37	84.3	2 247 212	112 110	32.90	36 884	1
Corporation Limited,	(8 950)	(2.95)	(7.11)	(0.40)	(79.9)	(3 109 140)	(154 844)	(34.97)	(54 149)	(1)
Bathurst										
Heath Steele Mines Limited,	3 650	1.85	4.53	0.99	77.8	1 052 568	34 365	31.11	13 263	3,5,6,8
Newcastle	(2 800)	(1.54)	3.99	(1.03)	(59.3)	(988 326)	(28 166)	(26.48)	(9 393)	(3,5,6,8)
Nigadoo River Mines Limited,	1 050	2.43	2.63	0.16	93.9	198 698	8 044	52.02	4 185	2
Bathurst	(1 050)	(2.55)	(2.69)	(0.25)	(117.9)	(231 403)	(7 627)	(52.11)	(5 160)	(2)
Quebec										
Manitou-Barvue Mines Limited,[3]	1 450	0.51	3.13	—	97.0	96 836	. .	. .	373	3
Golden Manitou Mine,	(1 450)	(0.30)	(1.81)	(—)	(81.9)	(222 256)	(1 335)	(30.0)	(411)	(3)
Val d'Or										
Sullivan Mining Group Ltd.,[4]	1 300	. .	. .	. .	. .	. .	. .	. .	108	2
Startford Centre,	(1 300)	(0.47)	(4.12)	(2.24)	(33.3)	(50 855)	(230)	(61.58)	(142)	(2)
Cupra Division										
D'Estrie Mining Company Ltd.[4]	treated at	. .	. .	. .	. .	. .	. .	. .	403	2
	Cupra	(0.54)	(2.12)	(2.57)	(38.3)	(163 379)	(852)	(61.41)	(523)	(2)
	mill									
Clinton Copper Mines Ltd.	treated at		Closed in mid-1975			—	—	—	—	—
	Cupra	(0.47)	(2.49)	(2.59)	(30.0)	(66 710)	(204)	(59.32)	(121)	(2)
	mill									
Louvem Mining	1 450	. .	5.99	—	56.2	258 534	507	29.12	148	3
Company Inc[3]	(1 450)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)	(—)
Val d'Or										

Table 3. (cont'd)

Company and Location	Mill Capacity	Grade of Ore Milled: Lead	Zinc	Copper	Silver	Ore Milled	Lead Concentrate Produced	Grade of Lead in Concentrate	Contained[1] Lead Produced	Destination[2] of Lead Concentrate
	(tonnes per day)	(%)	(%)	(%)	(g/tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Ontario										
Falconbridge Copper Limited,	1 100	1.23	9.57	2.15	183.8	377 257	1 663	32.95	548	1,3
Sturgeon Lake Joint Venture,	(1 100)	(1.17)	(9.07)	(2.78)	(182.1)	(341 720)	(2 251)	(7.78)	(253)	(8)
Sturgeon Lake										
Mattabi Mines Limited,	2 700	0.76	8.13	1.23	121.0	966 797	3 941	51.93	2 047	2
Sturgeon Lake	(2 700)	(0.70)	(7.34)	(0.97)	(110.7)	(975 154)	(3 573)	(50.77)	(1 814)	(2,6)
Noranda Mines Limited,	4 550	0.12	2.55	1.69	44.2	1 529 781	1 406	56.71	1 515	3
Geco Division,	(4 550)	(. .)	(3.54)	(1.84)	(49.4)	(1 450 891)	(1 718)	(47.94)	(1 659)	(2)
Manitouwadge										
Texasgulf Canada Ltd.,	9 050	0.30	8.05	1.73	119.7	3 242 279	35 017	12.13	4 649	3
Kidd Creek mine,	(9 050)	(0.25)	(8.20)	(1.71)	(106.3)	(3 293 285)	(28 643)	(12.83)	(5 932)	(3)
Timmins										
Willroy Mines Limited,	1 450	0.17	3.67	0.56	54.5	311 430	749	34.46	237	2
Manitouwadge Division,	(1 300)	(0.22)	(3.82)	(0.42)	(53.5)	(296 970)	(1 285)	(30.99)	(398)	(2)
Manitouwadge										
Manitoba and Saskatchewan										
Hudson Bay Mining and	7 700	0.2	2.7	2.3	20.6	1 417 617	457	69.0	315	2
Smelting Co., Limited,	(7 700)	(0.2)	(3.0)	(2.4)	(20.6)	(1 333 704)	(208)	(69.9)	(145)	(2)
Flin Flon										
British Columbia										
Cominco Ltd.,	9 050	4.0	3.95	–	45.9	2 124 892	109 675	62.6	77 302	2
Sullivan Mine,	(7 250)	(3.85)	(4.16)	(–)	(43.5)	(2 002 927)	(85 772)	(62.92)	(67 494)	(2)
Kimberly										
H.B. mine,	1 100	0.69	3.82	–	. .	374 803	5 096	31.1	2 065	2
Salmo	(1 100)	(0.56)	(3.40)	(–)	(. .)	(411 086)	(4 986)	(23.5)	(1 477)	(2)
Consolidated Columbia River[4]	300	. .	. .	. .	. .	42 000	1 400	60.0	840	2
Mines Ltd. (N.P.L.),	(300)	(. .)	(. .)	(. .)	(. .)	(10 258)	(356)	(50.20)	(189)	(2)
Ruth Vermont mine,										
Golden										
Kam-Kotia Mines Limited,	100	5.3	4.86	–	457.7	16 694	1 412	59.23	836	2
Silmonac mine,	(100)	(5.66)	(4.82)	(–)	(599.3)	(10 927)	(982)	58.74	591	(2)
Sandon										

Table 3. (concl'd)

Company and Location	Mill Capacity	Grade of Ore Milled: Lead	Zinc	Copper	Silver	Ore Milled	Lead Concentrate Produced	Grade of Lead in Concentrate	Contained[1] Lead Produced	Destination[2] of Lead Concentrate
	(tonnes per day)	(%)	(%)	(%)	(g/tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
British Columbia (concl'd)										
Northair Mines Ltd.,	250	0.86	1.81	–	111.8	47 554	876	34.7	341	3
Squamish	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Reeves MacDonald Mines	–	Closed March 31, 1975				–	–	–	–	–
Limited,	(900)	(0.58)	(3.07)	(–)	(20.6)	(32 211)	(273)	(11.19)	(151)	(3)
Annex mine,										
Remac										
Teck Corporation Limited,	100	0.43	0.54	–	336.3	34 448	836	17.14	148	2
Beaverdell mine,	(100)	(0.38)	(0.39)	(–)	(318.8)	(34 898)	(704)	(16.16)	(132)	(2)
Beaverdell										
Western Mines Limited,	1 000	1.42	7.73	1.19	169.4	269 294	7 240	42.92	3 586	2
Lynx and Myra Falls,	(1 000)	(1.42)	(7.59)	(1.12)	(153.9)	(260 719)	(6 906)	(43.5)	(3 419)	(2)
Buttle Lake, V.I.										
Yukon Territory										
Cyprus Anvil Mining	9 050	2.66	5.48	–	0.5	1 519 880	43 421	67.28	33 070	4,5
Corporation,	(9 050)	(4.03)	(5.41)	(–)	(. .)	(2 925 874)	(131 953)	(66.89)	(105 380)	(2,3,4,5,7,8)
Faro										
(Also bulk							24 622	15.65	included	included
lead-zinc							(69 956)	(18.37)	above	above
concentrate)										
United Keno Hill Mines Limited	450	4.02	1.17	–	1 216.8	68 506	3 805	59.0	2 227	3
Elsa, Husky, No Cash and	(450)	(4.03)	(1.15)	(–)	1 128.7	(82 427)	(5 561)	(53.57)	(2 979)	(3)
Keno mines,										
Elsa										
Northwest Territories										
Nanisivik Mines Ltd.,	1 350	2.9	14.5	–	. .	70 760	434	47.4	943	stockpiled
Baffin Island	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)	(–)
Pine Point Mines Limited,	9 050	1.70	5.30	–	–	3 422 833	66 688	74.44	55 334	2,3,4,5,6,8
Pine Point	(9 050)	(2.37)	(4.88)	(–)	(–)	(3 542 264)	(94 597)	(78.16)	(79 185)	(2,3,4,8)

Source: Data supplied by companies to Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Total lead contained in all concentrates. [2]Destination: (1) Brunswick Mining and Smelting Corp; (2) Cominco Ltd.; (3) U.S.A.; (4) Japan; (5) Germany; (6) Belgium; (7) United Kingdom; (8) Unspecified, or other countries. [3]Louvem purchased Golden Manitou mine and mill on August 11, 1976. [4]Production estimated from reports in the technical press.

Table 4. Prospective Canadian lead producing mines

Company and Location	Year Production Expected	Mill or Mine Capacity	Indicated Ore Reserves	Grade of Ore: Zinc	Grade of Ore: Lead	Grade of Ore: Copper	Grade of Ore: Silver	Remarks
		(tonnes ore/day)	(tonnes)	(%)	(%)	(%)	(g/tonne)	
Nova Scotia								
Cuvier Mines Ltd., Gays River	1980-'85	. .	10 900 000	5.6	2.3	—	. .	Optioned to Imperial Oil Limited. Under exploration since 1972. Full potential not yet determined. Feasibility study results should be announced in 1977.
Ontario								
Mattagami Lake Mines Limited, Lyon Mine, Sturgeon Lake	1977	900	3 700 000	6.66	0.63	1.15	116	Ore to be processed at Mattabi Mines Ltd.
Yukon Territory								
Canex Placer Limited, Howards Pass, Summit Lake	1980-'85	. .	270 000 000		About 5-10 (Pb + Zn)			Joint exploration with United States Steel Corporation. Drilling to continue in 1977 and 80 kilometre access road being constructed.
Hudson Bay Mining and Smelting Co., Limited Tom deposit, MacMillan Pass	1980-'85	. .	7 850 000	8.4	8.1	—	94	Underground work through adit, including diamond drilling in 1970-72. Further development planned.
Kerr Addison Mines Limited - Canadian Natural Resources Limited, Grum deposit, Vangorda Creek	1979-'83	5 000	26 100 000	6.43	4.07	—	62	Similar to Cyprus Anvil lead-zinc deposit. $6.25 million program undertaken in 1975, including 800 m. decline into ore body. Feasibility study concluded late 1976. Announcement probable in 1977, pending negotiations with federal government.

Table 4. (concl'd)

Company and Location	Year Production Expected	Mill or Mine Capacity	Indicated Ore Reserves	Grade of Ore: Zinc	Lead	Copper	Silver	Remarks
		(tonnes ore/day)	(tonnes)	(%)	(%)	(%)	(g/tonne)	
Northwest Territories								
Arvik Mines Ltd., Little Cornwallis Island	1980-'85	. .	22 700 000	14.1	4.3	. .	34	Cominco Ltd., 75% and Bankeno Mines Limited, 25%. Underground program (1,600-metre adit) and metallurgical tests completed. Feasibility study completed. Decision on mining depends on negotiations with federal government.
Western Mines Limited - DuPont of Canada Exploration Limited, Pine Point	1980-'85	. .	2 540 000	11.9	4.1	—	. .	Further exploration and diamond drilling planned for 1977

Sources: Company reports and technical press.
— Nil; . . Not available.

Table 5. Indicated lead deposits under exploration

Company and Location	Indicated Ore Tonnage	Grade of Ore: Zinc	Lead	Copper	Silver	Remarks
	(tonnes)	(%)	(%)	(%)	(g/tonne)	
Nova Scotia						
Barymin Explorations Limited, Cape Breton	71 000 000	—	2.09	—	—	Increased price of lead has renewed interest in this deposit. Exploration and diamond drilling planned for 1977. Contains 6.2 million tonnes grading 4.95 per cent lead.
New Brunswick						
Anaconda Canada Limited, Bathurst, Caribou property	45 360 000	4.48	1.7	0.47	59	In temporary production in 1971 and 1974. Feasibility studies continue on bringing this property into production (late 1970s?).
Canex Placer Limited, Portage Lakes area, Restigouche property	2 700 000	6.0	4.5	. .	86	Partly recoverable by open pit. Further exploration in 1977.

Table 5. (cont'd)

Company and Location	Indicated Ore Tonnage	Grade of Ore: Zinc	Lead	Copper	Silver	Remarks
	(tonnes)	(%)	(%)	(%)	(g/tonne)	
New Brunswick (cont'd)						
Murray-Brook property	21 400 000	3.0 (Pb+ Zn)		0.4		Exploration continuing in 1977.
Chester Mines Limited, Newcastle	1 450 000	2.12	0.83	0.63	. .	Ore available for open-pit mining.
	3 000 000	—	—	0.82	—	Ore available for underground mining. Feasibility study completed in 1970. Metallurgical work continued in 1976 with test milling of copper ore at the Nigadoo mill.
	11 800 000	—	—	0.77	. .	
Key Anacon Mines Limited, Bathurst	1 800 000	5.87	2.18	0.24	79	Mine partly developed. valuation of property in 1970 led to decision to defer placing the property into production at that time.
Texasgulf Inc., Half Mile Lake	6 200 000	6.5	2.5	. .	. .	Plans to sink and exploratory shaft have been deferred but diamond drilling is continuing.
Ontario						
Giant Yellowknife Mines Limited, Errington and Vermilion Lake mines, Sudbury area	4 008 400 and 8 200 000	3.9 3.82	1.0 0.99	1.33 1.14	55 54	Extensive underground development in 1961-'67 period. Ore difficult to concentrate. Reserves only for underground explored areas with low-pyrite and high-pyrite ore, respectively.
British Columbia						
Barrier Reef Resources Ltd. Robb Lake	5 530 000	About 7.3 per cent Pb+ Zn				Drilling discontinued in 1976.
Yukon Territory						
Kerr Addison Mines Limited Swim Lake deposit, Vangorda Creek	4 500 000	5.5	4.0	. .	52	'A' group claims. Production probably dependent on development of Grum deposit.
Vangorda Mines Limited, Vangorda Creek	8 500 000	4.96	3.18	0.27	60	Feasibility study made. No further exploration. Production probably depends on development of Grum deposit.

Table 5. (concl'd)

Company and Location	Indicated Ore Tonnage	Grade of Ore Zinc	Lead	Copper	Silver	Remarks
	(tonnes)	(%)	(%)	(%)	(g/tonne)	
Northwest Territories						
Bathurst Norsemines Ltd., Hackett River, Bathurst Inlet area	19 500 000	4.98	0.75	0.41	150	Optioned to Cominco. Large deposit in three zones with high zinc and silver values, also some gold. Under active exploration from 1970, and $2 million expended by December 1975. Wright Engineers performed $100,000 feasibility study in 1976 but results not yet announced.
Buffalo River Exploration Limited	1 350 000	9.6	3.4	—	. .	Feasibility study for joint production with Coronet Mines Ltd. completed in 1971. Decision made not to put the property into production at present.
Texasgulf Inc., Izok Lake	11 000 000	13.8	1.4	2.8	7.0	Central ore zone, which is open to east. Remaining two zones not delineated and drilling to continue in 1977.
Welcome North Mines Ltd. Bear Property, Godlin Lake	18 150 000		About 7-8 (Pb+ Zn)	. .	17-34	Drilling continues.

Sources: Company reports and technical press.
. . Not available; — Nil.

Table 8. Non-communist world production[1] of refined lead, 1975-76

	1975	1976^{p}
	(tonnes)	
United States	1 056 800	1 042 900
West Germany	257 100	274 900
United Kingdom	228 500	225 500
Japan	194 200	219 000
Australia	193 500	212 000
Mexico	175 000	185 000
Canada	171 500	175 700
France	151 000	172 600
Yugoslavia	130 000	119 000
Italy	90 000	109 500
Belgium	103 000	104 400
Spain	101 000	74 100
Peru	71 000	72 000
Republic of South Africa	57 500	50 000
Argentina	47 000	50 000
Brazil	38 000	48 000
Sweden	36 900	33 600
Other countries	166 100	169 300
Total	3 268 100	3 337 500

Sources: For Canada, Statistics Canada; for all other countries International Lead and Zinc Study Group, Monthly Bulletin, April, 1977.
[1]Total production by smelters or refineries, of refined pig lead, plus the lead content of antimonial lead — including production on toll in the reporting country — regardless of the type of source material, i.e., whether ores, concentrates, lead bullion, lead alloys, mattes, residues, slag or scrap. Remelted pig lead and remelted antimonial lead are excluded.
^{p}Preliminary.

the United States affected metal production in the first and fourth quarters of the year respectively. Also, the mine strikes in Canada affected metal production in Japan as concentrate supplies became tight in the last quarter.

During 1976 primary plants totalling 138 000 tonnes of metal-producing capacity were closed and replaced by plants totalling 246 000 tonnes. This new capacity is located in: Mexico, 190 000 tonnes; Spain, 40 000 tonnes; India, 10 000 tonnes and Turkey, 6000 tonnes.

Secondary plants totalling 42 000 tonnes of annual capacity were closed in 1976, while a total of 128 000 tonnes was added, comprising 30 000 tonnes in the United States, 18 000 tonnes in India, 40 000 tonnes in Brazil, 30 000 tonnes in Sweden and 10 000 tonnes in Italy. Thus, net additions to world metal-producing capacity in 1976 totalled 194 000 tonnes in the primary and secondary sectors combined.

Consumption. Statistics from the International Lead & Zinc Study Group (ILZSG) show that consumption increased 7.4 per cent in 1976 to a level of 3 396 000 tonnes compared with 3 161 000 tonnes in 1975. The EEC showed a gain of 14 per cent, while consumption increased 22 per cent in Japan and 10 per cent in the United States. Smaller increases were recorded for most other countries, with only the Central and South American group of nations actually reporting a small decline.

Uses. Lead has many useful chemical properties and, because of this versatility, it has a variety of industrial applications. It is soft, ductile, alloys readily with other materials, has good corrosion resistance, a high boiling point, a low melting point and a high specific gravity. Lead is one of the oldest metals known to man and since medieval times has been used in piping, building materials, solders, paint, type metal, ammunition and castings.

Lead is used mainly in lead-acid storage batteries, the bulk of which are used for starting, lighting and ignition (SLI) in automobiles and trucks. Recent improvements in battery manufacture have significantly reduced the weight of lead in a battery unit to about 10 kilograms and increased the average battery life to about three years. New maintenance-free batteries using a calcium-lead alloy instead of lead-antimony reportedly have a service life of five to six years. Usage of lead in the manufacture of all types of batteries is expected to continue to grow at a rate of about 5.5 per cent per annum, and by 1980 to account for 50 per cent of total lead consumption. This growth will come from increased automobile production and

Table 9. Canada, lead production and consumption 1974-77, 1980

	1974	1975	1976	1977^{f}	1980^{f}
Mine Production	301	352	247	335	365
Metal Production (Primary)	126	171	176	185	210
Consumption[1]	100	89	98^{e}	100	110

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
^{e}estimate; ^{f}Forecast.
[1]Includes consumption of secondary lead.

from rapid growth in the use of electric-powered industrial trucks (particularly fork-lift vehicles). Many governments in Europe and North America have experimental transportation programs involving battery systems as the power source, replacing the internal combustion engine. A growing market for batteries involves their use for emergency power supply by such institutions as hospitals and for load levelling and peak power shaving in the electric utility industry.

The next most important use of lead is as an antiknock additive in gasoline. This use will decline as it comes under more strict environmental control regulations throughout the world. Lead consumed for batteries and gasoline additives in 1976 accounted for 72 per cent of total lead consumption in the United States. The metal is also used extensively for cable sheathing, collapsible tubes, caulking materials, ammunition, corrosive-liquid containers, galvanizing spelter and lead-base babbitts.

The commercial and residential construction industry is a growing market for lead in the form of soundproofing, flashing and construction panels. Because of its unique sound-control characteristics there is an expanding use for lead in sound attenuation both as sheets and lead-composition panelling. Composite thermal-accoustical panels are now being used to contain the noise from industrial plants. Lead-coated steel sheeting (terne steel) that combines lead's corrosion resistance and sound-barrier properties with the strength of steel is now available for many building applications. Terne steel is sheet steel coated with an alloy containing 85 per cent lead. In the allied field of vibration isolation, lead-asbestos antivibration pads are now being widely used in foundations for office buildings, and in hotel and apartments exposed to severe vibration from nearby heavy traffic. Because of its sound-control qualities, lead is also used in the mounting of various types of equipment, including air-conditioning systems, heavy industrial equipment and commercial laundry machines.

The use of lead chromate paints on highways for pavement marking is growing because it is the most versatile low-cost pigment available for traffic-control paints. Corrosion-resistant lead paint is a standard primer for iron and steel structures.

Miscellaneous uses for lead include glassware, automotive wheel weights, ship ballast, various alloys and as lead-ferrite for permanent magnets in small electric motors. Relatively new and growing areas of use are for radiation shielding in nuclear-powered reactors, nuclear-powered ships and submarines, and shipping casks for transporting radio-active materials. Continuing research has developed new and promising markets for organometallic lead compounds in such applications as anti-fouling paints, wood and cotton preservatives, lubricant-oil additives, polymethane foam catalysts, molluscides, antibacterial agents and rodent repellents.

Refined lead is marketed in several grades that vary mainly according to the content of impurities, including silver, copper, arsenic, antimony, tin, zinc, iron and bismuth. The three principal grades are corroding, chemical and common desilverized lead. The corroding grade has the highest purity and is used chiefly in the manufacture of pigments, battery oxides and tetraethyl lead. Common lead is used mostly in industrial and home construction, while chemical lead possesses superior creep and corrosion resistance and is ideally suited for cable sheathing.

Prices. Prices for lead metal in all major markets reached new highs in 1976. Inventories declined throughout the year and metal demand was strong, particularly in the last quarter.

The Canadian producer price of virgin lead, delivered, increased from 18.5 cents a pound on January 1 to a split price of 25.5 to 26.5 cents a pound at year-end.

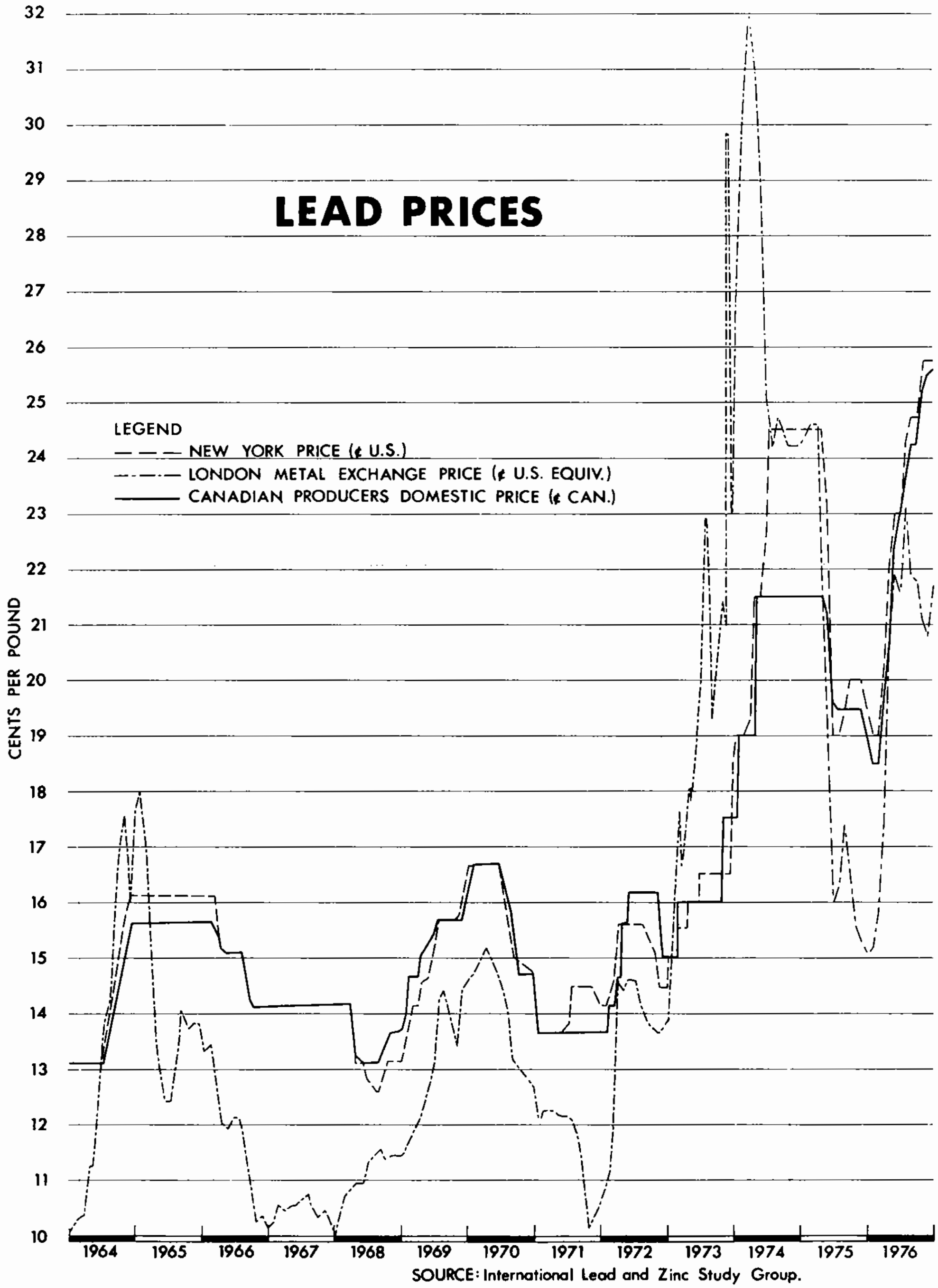
The United States producer price of virgin lead, delivered, followed the same pattern as in Canada. The January 1 price was 19.0 cents a pound but as the domestic economy began to pick up, a series of price increases brought the quoted price to 25.5 to 26.0 cents a pound at year-end.

The London Metal Exchange (LME) spot price, after hitting a low for the year of £164.25 a tonne (15.2c Cdn. a pound) on January 19, exhibited strength during the rest of the year and reached the year's high on December 22 of £302 a tonne (23.4c Cdn. a pound). The spot price monthly average rose during the year from £165.8 for January to £284.7 a tonne for December.

All indicators point to continuing strength in the lead price in 1977 and a number of price increases in the first quarter of 1977 brought the lead price to a level of 31 cents a pound in North America. Strikes and replacement battery demand played a large part in keeping the supply of metal tight during late 1976 and early 1977 and although the battery demand is expected to ease during the balance of 1977, the disruptions in supply and general improvement in economic activity may result in a further 5 to 10 per cent increase in the price.

Outlook

Canada. Mine production will show a substantial gain in 1977 as producers recover from the strike-induced low of 1976. The period from 1977 to 1980 should be one of modest growth. New production was added in 1976 as Northair and Nanisivik came into production and Heath Steele completed its expansion program. Further increases in output during this period will come from existing producers that are presently in the midst of expansion programs. Some of this expanded capacity, plus improvements in technical efficiency, will be balanced by closures and declines from other producers mining lower grades of ore. The mine production forecast (Table 9) could be on the conservative


LEAD PRICES
LEGEND
NEW YORK PRICE (¢ U.S.)
LONDON METAL EXCHANGE PRICE (¢ U.S. EQUIV.)
CANADIAN PRODUCERS DOMESTIC PRICE (¢ CAN.)
CENTS PER POUND
32
31
30
29
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1964
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1971
1972
1973
1974
1975
1976
SOURCE: International Lead and Zinc Study Group.

side if certain projects such as Gays River, Grum or Arvik reach the production stage sooner than expected. Production from Canada's more-northern resources, particularly in the Yukon and Northwest Territories, is largely dependent on infrastructure developments in transportation and power.

The increase in metal output will result from higher utilization of existing plant capacity, presently 226 250 tonnes a year. The growth rate in consumption of lead in Canada in the period 1960 to 1975 was 3 per cent and although consumption has been erratic in this decade, it is expected that consumption in the 1977 to 1980 period will be at this historical level.

World. Information released by ILZSG in November shows lead mine production increasing by 225 000 tonnes in 1977 to 2 670 000 tonnes, about 10 per cent above the 1976 level of 2 445 000 tonnes. The main increases expected are in Europe (75 000 tonnes), in Canada (85 000 tonnes), in the United States (17 000), and in Australia (22 000). Lead metal production is expected to increase by about 8 per cent to 3 785 000 tonnes, and consumption to increase by about 5 per cent to 3 643 000 tonnes. With no changes expected in national stockpile levels, and net trade with socialist countries expected to be at about the 1976 level, the statistical balance shows a surplus of about 29 000 tonnes. As a result, inventory levels should remain little changed in 1977 unless disruptions occur in supply.

There are key problems facing industrialized countries in 1977. The rate of economic recovery through 1976 has been slow and erratic, unemployment rates remain high, while inflation, through moderating, is still above acceptable levels. The problem is whether governments should be more stimulative in their monetary and fiscal policies, thus risking a new round of inflation, or take a cautionary, slow-growth approach which will keep demand and prices in check while leaving unemployment rates high. The ILZSG forecast for the lead industry in 1977 reflects the expected developments if the latter path is followed.

In the period from 1976 to 1980 new lead mine projects plus expansions at existing facilities will add a total of about 292 000 tonnes a year to world capacity. This total is broken down into 175 000 tonnes from new mines and 117 000 tonnes from expansions. The largest single project in this four-year period is the Tara mine in Ireland which will have the capacity to produce about 47 000 tonnes of lead annually, beginning in 1977. Broken down by continents; new capacity and expansions total 147 000 tonnes in Europe, 19 000 tonnes in Africa, 24 000 tonnes in Asia, 23 000 tonnes in Oceania and 79 000 tonnes in the Americas. During the same period, declining output from existing producers, closures and unforeseen supply disruptions will keep the overall increase in output much lower than the above figures suggest.

Expansions and new additions to lead metal production capacity in the same period can be characterized as follows. Capacity in the primary sector will increase by 69 000 tonnes, while increases in the secondary sector total 397 000 tonnes. On the primary side, 29 000 tonnes of the expansion is located in industrialized countries of Europe, while the remainder is in Turkey, India and Brazil. Expansions in the secondary sector are located in Europe (46 000 tonnes), the United States (287 000), Brazil (40 000) and India (24 000). It is becoming increasingly apparent that the global evolution of the lead industry is resulting in a shift of primary smelting capacity to the countries which are ore sources. In many cases this coincides with a shift of smelter capacity (relatively) to developing countries. This trend is likely to gain strength in the 1980s while industrialized countries are increasingly emphasizing the recovery and recycling of secondary materials. Most industrial countries currently satisfy about 30 to 35 per cent of their metal requirements from production by the secondary sector. This percentage will probably approach 40 per cent, on average, in the early 1980s.

Table 11 is a forecast of the western world lead balance to 1985. The major conclusions to be drawn from the table are that: mine production growth is likely to be about 0.5 per cent per annum during the period, with no real growth occurring between now and 1980; the growth in secondary supply will have to be 4.0 per cent or better in order to achieve a balance between supply and demand; and the overall net deficits (calculated by determining the "expected" secondary supply as opposed to the "needed" secondary supply) are within the margin of error for balance (±100 000 tonnes) except at consumption growth rates of 2.0 per cent and greater. It is clear that either the price of lead will have to increase substantially in order to call out new supplies or the demand for lead will need to be less than 2.0 per cent per annum (with perhaps substitution in some cases being a factor in helping to keep prices low). Nonetheless, the lead market likely will be in a tight-supply position throughout the period. The greatest unknown in developing a forecast such as this for the lead industry is the capacity and capability of the secondary industry to respond to increased demand. Also, the starting point does not take into account the existing level of producer and consumer inventories. For the purposes of this forecast it has been assumed that inventory level changes will balance out during the period, particularly so since the levels were normal by year-end 1976. The capacity and responsiveness of the secondary industry sector is still largely unknown.

Table 10. Location of new or expanded smelter capacity

Expected Start-up Year	Country	Company	Location	Type of Plant	Additional Capacity (tonnes a year)	Remarks
1977	Brazil	Tonolli	Jacarei	Secondary smelter	40 000	New plant
	India	Hindustan Zinc Co.	Vishakhapatnam	Pyrometallurgical smelter	10 000	New plant under construction.
	Italy	Ammi	San Gavino	Refinery	7 000	Expansion of existing plant
	Nigeria	Nigerian Smelting Refining	—	Secondary smelter	5 000	New plant
	Spain	Tudor	Junquera de Henares	Secondary smelter	9 000	New plant
	United Kingdom	Britannia Lead	Northfleet	Secondary plant	30 000	New plant
	United States	N L Industries, Inc.	Pedricktown, N.J.	Secondary plant	65 000	Expansion of 35 000-tonne plant in stages through 1979.
			Beech Grove, Ind.	Secondary plant	70 000	Expansion of 30 000-tonne plant in stages through 1979.
			Los Angeles, Cal.	Secondary plant	65 000	Expansion of 35 000-tonne plant — complete in 1977.
		Schuylkill Metals	Mound City, Mo.	Secondary smelter	30 000	New plant
		Mincon	Muncie, Ind.	Secondary smelter	27 000	New plant
		Refined Metals	Memphis, Tenn.	Secondary plant	9 000	Expansion from 9 000 tonnes
		Corp.	Jacksonville, Tenn.	Secondary plant	8 000	Expansion from 8 000 tonnes
1978	Brazil	Metamig	Poracatu	New plant	11 000	New plant
1980	Brazil	Cobrac	Santo Amaro	Primary plant	13 000	Expansion from 32 000-tonne capacity

Sources: International Lead and Zinc Study Group; technical press.
— Not available.

Table 11. Apparent Western World lead balance, 1977 to 1985

	1977[r]	1978	1979	1980	1981	1982	1983	1984	1985	Comment
				(000 tonnes)						
Base mine production	2 662	2 662	2 664	2 630	2 651	2 668	2 703	2 737	2 822	
Less allowance for reduced ore and grade[1]		59	59	58	58	59	60	61	61	2.2 per cent
Plus production from new capacity		61	25	79	75	75	75	145	145	@ 85 per cent
Total Western World production[2]	2 662	2 664	2 630	2 651	2 668	2 703	2 737	2 822	2 905	
Losses net of secondary supply	80	80	79	80	80	81	82	85	87	@ 3.0 per cent
Primary refined equivalent mine production	2 582	2 584	2 551	2 571	2 588	2 622	2 655	2 737	2 818	
Metal consumption — 1976 base — 3396 (primary and secondary)										
Annual growth rate — 1.8%	3 457	3 519	3 583	3 647	3 713	3 780	3 848	3 917	3 987	
2.0%				3 676					4 059	
2.5% U.S. } 3.0% rest of world				3 797					4 365	
Plus exports to Socialist countries	+86	+80	+75	+70	+65	+60	+55	+50	+45	
Net change in national stockpiles	—	+30	+30	+30	+30	+30	+30	+30	+30	(U.S.A., France, India and Japan)
Net Metal demand	3 543	3 629	3 688	3 747	3 808	3 870	3 933	3 997	4 062	
				3 776					4 134	
				3 897					4 440	
Needed Secondary[3] Supply to Achieve Balance	961	1 045	1 137	1 176	1 220	1 248	1 278	1 260	1 244	3.3% Growth Rate
				1 205					1 316	4.0% Growth Rate
				1 326					1 622	6.0% Growth Rate
Secondary supply at historical rate[4] of 26% of consumption 1960-1975 plus 0.5% increments to 1985[5]	957	998	1 033	1 068	1 104	1 142	1 180	1 219	1 259	
				1 076					1 282	
				1 111					1 376	
Total balance – surplus (deficit)	(4)	(47)	(104)	(108)	(116)	(106)	(98)	(41)	15	
	(7)	(57)	(119)	(129)	(141)	(137)	(135)	(84)	(34)	
	(30)	(99)	(183)	(215)	(251)	(272)	(294)	(269)	(246)	

Source: Mineral Development Sector, Department of Energy, Mines and Resources.
[1]Accounts for the decline in production from the existing stock of producers. [2] Equates to a growth rate in mine production of 1.1% per annum over the period 1977 to 1985. [3]Includes secondary metal, inventory changes and releases from government stockpiles. [4]Five-year rolling average. [5]Accounts for additions to secondary metal capacity.

[r] Revised ILZSG. — Nil.

Tariffs

Canada

Item No.		G.S.P.[1]	British Preferential	Most Favoured Nation	General
32900-1	Ores of lead	Free	Free	Free	Free
33700-1	Lead, old scrap, pig and block	Free	Free	Free	1c/lb
33800-1	Lead, in bars and in sheets	3%	5%	5%	25%
33900-1	Manufactures of lead n.o.p.	11½%	17½%	17½%	30%

United States

U.S.T.S. No.	Effective Nov. 21, 1975	G.S.P.	Most Favoured Nation (¢/lb on lead content)	
602.10	All lead bearing ore	Free	0.75	
Unwrought				
624.02	Lead bullion	free	1.0625	
624.03	Other		1.0625	
624.04	Lead waste and scrap	Free	1.0625	(on 99.6% of lead content)

European Economic Community (EEC)

238-6464

BTN No.		G.S.P.	Most Favoured Nation
26.01	Lead ore and concentrates	Free	Free
78.01	Unwrought lead:		
	For refining (i.e. argentiferous)	Free	Free
	Other	3.5%	3.5%
	Lead waste and scrap	Free	Free

Japan

BTN No.		G.S.P.	Most Favoured Nation
26.01	Lead ore and concentrates	Free	Free
78.01	Unwrought lead		
	Unalloyed	Free	7.5%[2]
	Alloyed	Free	7% to 12%[2]
	Lead waste and scrap	Free	5%[2]

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976, TC Publication 749). For Japan, Customs Tariff Schedules of Japan, 1976, Japan Tariff Association. For EEC, Official Journal of the European Communities, Vol. 19, No. L314, 1976.

[1]GSP – Generalized System of Preferences extended to all, or most, developing countries; some GSP rates are subject to quotas or withdrawals. [2]Subject to a temporary reduction of 20 per cent.

1976 Tariffs done by Fraser + co.

Lime

D.H. STONEHOUSE

Carbonate rocks, commonly known as limestones, can be classified according to their content of the minerals calcite ($CaCO_3$) and dolomite ($CaCO_3 \cdot MgCO_3$). They range from calcium limestone containing less than 10 per cent magnesium carbonate to magnesian limestone containing between 10 and 40 per cent magnesium carbonate and to dolomite containing between 40 and 45.65 per cent magnesium carbonate. High-calcium limestones are those with less than 3 per cent total impurities. Limestones vary in colour, texture and hardness as well as in chemical composition, giving rise to a wide range of applications. Quicklime (CaO or CaO MgO) is formed by the process of calcination, in which limestones are heated to the dissociation temperature of the carbonates (as low as 402°C for $MgCO_3$ and as high as 898°C for $CaCO_3$) and held at that temperature over sufficient time to release carbon dioxide. Although the word "lime" is used generally, and wrongly, to refer to pulverized limestone as well as to forms of burned lime, it should refer only to calcined limestone (quicklime) and its secondary products, slaked lime and hydrated lime. Slaked lime is the product of mixing quicklime and water, hydrated lime is slaked lime dried and, possibly, reground.

Calcining is done in kilns of various types but, essentially those of vertical or rotary design are used, having incorporated many adaptations to the standard designs over the years. Of comparatively recent design are the rotary hearth, travelling grate, fluo-solid and inclined vibratory types. The high cost of energy has made it imperative to include preheating facilities in any new plant design, and environmental regulations have necessitated the incorporation of dust-collection equipment.

Canadian industry and developments

Lime plants have been established near urban and industrial centres in Canada where large reserves of suitable limestone are available and where most of the major consumers of lime are situated. Lime is a high-bulk, low-cost commodity and it is uncommon to ship it long distances when the raw material for its manufacture is available in so many localities. The more heavily populated and industrialized provinces of Ontario and Quebec together produced over 80 per cent of Canada's total lime output in 1976, with Ontario contributing about one-half of Canada's total. More limited markets in the other provinces resulted in much lower production in those areas. Commercial lime (lime that is normally produced for shipment and use off the plant site) was not produced in 1976 in Nova Scotia, Prince Edward Island, Newfoundland or Saskatchewan; the needs in each of these provinces being supplied from plants in neighbouring provinces or states.

During 1976, 18 companies operated a total of 24 lime plants in Canada: one in New Brunswick, four in Quebec, ten in Ontario, three in Manitoba, four in Alberta and two in British Columbia. A total of 85 kilns was available: 27 rotary, 54 vertical, one vibratory grate and three rotary grate. Preliminary returns indicate that lime production in 1976 was over 1.8 million tonnes*, up 14 per cent from 1975 despite poor performances by both the steel and pulp and paper industries, each of which are major consumers of lime. Production figures do not include some captive production such as that from pulp and paper plants that burn sludge to recover lime for re-use in the causticization process. Apparent production capability remained in the range of 2.3 to 2.5 million tonnes a year which would indicate that the industry operated at about 75 per cent efficiency during 1976. In certain regions, where supply has been running close to demand, increases in capacity are already underway — Joliette, Quebec (Domtar Chemicals Limited) and Beachville, Ontario (BeachviLime Limited).

Atlantic provinces. In 1968 at Aguathuna, near Stephenville on the west coast of Newfoundland, Sea Mining Corporation Limited constructed a new plant designed to produce magnesium hydroxide from seawater. Although the plant never operated commer-

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

cially, a rotary kiln, which was installed to produce lime for captive use in the extraction process, was put into service during 1969 and 1970 to supply some quicklime for waste-neutralization application on the island's east coast. This market is now supplied by Quebec-based lime producers.

Havelock Processing Ltd. began production of a high-calcium quicklime early in 1971, utilizing a newly installed, 90-tonne-a-day rotary kiln at the company's quarry site at Havelock, New Brunswick. Markets currently include mineral processing operations, pulp and paper industries, mainly within the province; and a growing export trade. Havelock Lime Works Ltd. operates the company's crushed limestone plant which has been expanded to offer a range of products from coarse aggregate through washed and screened sizes for asphalt and concrete application to finely pulverized filler material. Snowflake Lime, Limited which, for many years, produced lime at Saint John, has not rebuilt its lime-making facility following a fire in 1968. The quarries are still supplying crushed stone to the local construction industry.

Periodically during the last few years the possibility of establishing a lime producer in the northeast region of New Brunswick has been investigated. Limestone in sufficient quantity and of acceptable quality has been proved in the Elm Tree area but, although market projections indicate an increasing demand for lime in the mining and pulp and paper industries in this area, the amount, in total, does not yet appear to warrant a second plant within the province.

Studies have been made to determine the viability of a lime-manufacturing plant in Nova Scotia associated with existing and planned steel-producing facilities. Limestone and dolomite for the Sydney steel plant currently come from Irish Cove and Frenchvale, N.S. respectively.

Quebec. At Joliette, Domtar Chemicals Limited, Lime Division, produces quicklime and hydrated lime

Table 1. Canada, lime production and trade, 1975-76

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
By type				
Quicklime	1 404 624		1 626 075	
Hydrated lime	197 000		198 925	
Total	1 601 624	46 906 613	1 825 000	54 099 000
By province				
Ontario	769 425	19 994 307	916 000	24 236 000
Quebec	581 244	19 008 992	622 000	20 570 000
Alberta	110 401	3 341 752	132 000	4 093 000
Manitoba	. .	2 246 231	. .	2 805 000
New Brunswick	. .	1 302 650	. .	1 440 000
British Columbia	36 027	1 012 681	34 000	955 000
Total	1 601 624	46 906 613	1 825 000	54 099 000
Imports				
Quick and hydrated				
United States	30 049	1 383 000	36 842	1 431 000
France	50	36 000	40	13 000
Total	30 099	1 419 000	36 882	1 444 000
Exports				
Quick and hydrated				
United States	232 796	6 268 000	309 332	10 167 000
Panama	1 238	76 000	—	—
Total	234 034	6 344 000	309 332	10 167 000

Source: Statistics Canada.
[1] Producers' shipments and quantities used by producers.
^{p} Preliminary; — Nil; . . Not available.

Table 2. Canada, lime production, trade and apparent consumption, 1965, 1970, 1974-76

	Production[1]					Apparent
	Quick	Hydrated	Total	Imports	Exports	Consumption[2]
	(tonnes)					
1965	1 215 978	254 028	1 470 006	22 983	217 120	1 275 869
1970	1 270 973	224 026	1 494 999	30 649	181 994	1 343 654
1974	1 710 069ʳ	248 773ʳ	1 958 842ʳ	21 024	386 650	1 593 216ʳ
1975	1 404 624	197 000	1 601 624	30 099ʳ	234 034	1 397 689
1976ᵖ	1 626 075	198 925	1 825 000	36 882	309 332	1 552 550

Source: Statistics Canada.
[1]Producers' shipments and quantities used by producers; [2]Production, plus imports, less exports.
ʳ Revised; ᵖPreliminary.

from a high-calcium Trenton limestone for the steel and pulp and paper industries. Plans to increase the output capacity of the Joliette plant have been completed and a new kiln which will double the plant capacity should be operative during 1978. Shipments are made to Atlantic consumers as well as to Quebec and Ontario.

Dominion Lime Ltd. produces high-calcium quicklime and hydrated lime from Silurian limestone at Lime Ridge, near Sherbrooke. Additional production capacity resulted from activation of a new rotary kiln during 1973. Markets include steel, pulp and paper, construction and agricultural industries.

A high-calcium Ordovician limestone of the Beekmantown Formation has been mined for many years by Shawinigan Chemicals Division of Gulf Oil Canada Limited, near Bedford, for use in the company's carbide plant at Shawinigan. The quality of the limestone makes it a highly acceptable material for the production of calcium carbide. Hydrated lime made during calcium carbide-acetylene manufacture is sold for commercial use. Early in 1977 Gulf announced plans to close the Shawinigan plant in 1978.

Ontario. Domtar Chemicals Limited, Lime Division, operates a limestone quarry and a lime plant at Beachville. The high-calcium limestone is mined, crushed, screened and used primarily as feed to the lime plant, which has both vertical and rotary kilns. A prolonged strike at the Beachville plant in the latter part of 1975 continued into February 1976 and greatly limited output for the year. At Hespeler, Domtar produces lime, crushed stone and agricultural limestone. The lime plant has vertical kilns and produces high-quality, white quicklime. Both plants also produce hydrated lime.

The Beachville plant of Cyanamid of Canada Limited, containing a rotary kiln and a calcimatic kiln, was sold to Dominion Foundries and Steel, Limited (Dofasco), Hamilton in 1973. Major renovations undertaken immediately following take-over increased the plant's lime-producing capability in order to supply increased demands for lime by Dofasco's basic oxygen furnaces and to supply other, non-captive markets. A current expansion program will nearly double the plant capacity by the addition of a new preheater kiln. The plant is known as BeachviLime Limited. Cyanamid stopped production from its Niagara Falls plant, the decision being influenced, at least in part, by the necessity to install a dust-collecting system in order to remain in production. Limestone for use as open-hearth and blast-furnace flux, for portland cement manufacture and as a pulverized stone is also produced at Beachville.

Through a subsidiary, Chemical Lime Limited, The Steel Company of Canada, Limited, Hamilton is supplied with flux stone and high-calcium lime from a quarry and lime plant near Ingersoll. Vertical kilns were installed at the lime plant in 1959. A new rotary kiln of 300-tonne-a-day capacity was installed in 1971 to supply projected requirements of the company's steel-manufacturing facilities at the Hilton Works.

Near Amherstburg, Allied Chemical Canada, Ltd. mines a high-calcium limestone for the production of lime which is used, along with salt from a nearby brine field, in the manufacture of soda ash. Canadian Gypsum Company, Limited produces a dolomitic lime near Guelph.

Early in 1969 Reiss Lime Company of Canada, Limited began construction of docking facilities on Lake Huron, just west of Spragge, to import limestone from the Rogers City area in Michigan for the manufacture of lime to be used in uranium processing. Production of high-calcium lime began in mid-1970 at an initial capacity of 60 000 tonnes a year. The company is owned by Denison Mines Limited and C. Reiss Coal Co. Wisconsin, U.S.A.

At Dundas, Steetley of Canada (Holdings) Limited produces deadburned dolomite from three rotary kilns, mainly for steel industry uses. The company also produces flux stone, crushed stone products and agricultural "lime".

Western provinces. In 1976, Steel Brothers Canada Ltd. operated limestone quarries at Spearhill and Faulkner in Manitoba, at Kananaskis, Alberta and at Pavilion Lake in British Columbia. The Spearhill lime plant, from which a white, high-calcium lime was produced, was phased out during 1976 following start-up of a new preheater kiln at Faulkner in June. The new plant, a duplicate of the Pavilion Lake plant which went on stream in early 1975 and is capable of producing over 300 mtpd, is coal-fired with oil back-up and has been run in at full capacity with comparatively few start-up problems. Stone from the Faulkner quarry is trucked to the company's Fort Whyte plant where a vibratory grate calciner is used in lime manufacture. Quicklime is supplied to chemical, metallurgical and construction industries as well as to a growing market in the waste treatment field. Limestone is supplied to The Manitoba Sugar Company, Limited from the Manitoba quarries.

The limestone quarry at Kananaskis is about seven miles west of the lime plant and provides kiln feed for the production of quicklime and hydrated lime. A second rotary kiln went on stream early in 1972, doubling the production capacity of the plant.

Table 3. Canadian lime industry, 1976

Company	Plant Location	Type of Quicklime
New Brunswick		
1. Havelock Processing Ltd.	Havelock	High-calcium
Quebec		
2. Dominion Lime Ltd.	Lime Ridge	High-calcium[2]
3. Domtar Chemicals Limited	Joliette	High-calcium[2]
4. Gulf Oil Canada Limited Shawinigan Chemical Division	Shawinigan	High-calcium[2]
5. Quebec Sugar Refinery[1]	St-Hilaire	High-calcium
Ontario		
6. The Algoma Steel Corporation Limited[1]	Sault Ste. Marie	High-calcium
7. Allied Chemical Canada, Ltd.[1]	Amherstburg	High-calcium
8. BeachviLime Limited	Beachville	High-calcium
9. Canadian Gypsum Company, Limited	Guelph	Dolomitic[2]
10. Chromasco Limited[1]	Haley	Dolomitic
11. Domtar Chemicals Limited	Beachville	High-calcium[2]
	Hespeler	Dolomitic[2]
12. Reiss Lime Company of Canada, Limited	Spragge	High-calcium
13. The Steel Company of Canada, Limited (Stelco)	Ingersoll	High-calcium[2]
14. Steetley of Canada (Holdings) Limited	Dundas	Dolomitic
Manitoba		
15. The Manitoba Sugar Company, Limited[1]	Fort Garry	High-calcium
16. Steel Brothers Canada Ltd.	Faulkner	High-calcium
	Fort Whyte	High-calcium
Alberta		
17. Canadian Sugar Factories Limited[1]	Taber	High-calcium
	Picture Butte	High-calcium
18. Steel Brothers Canada Ltd.	Kananaskis	High-calcium
19. Summit Lime Works Limited	Hazell	High-calcium and Dolomitic
British Columbia		
20. Steel Brothers Canada Ltd.	Kamloops	High-calcium
21. Columbia Lime Products Limited	Fort Langley	High-calcium

Source: Mineral Development Sector.
[1] Production for captive use. [2] Hydrated lime produced also.

Table 4. Canada, consumption of lime, quick and hydrated, 1974-75 (producers' shipments and quantities used by producers, by use)

	1974		1975[p]	
	(tonnes)	($000)	(tonnes)	($000)
Chemical and metallurgical				
Iron and steel plants	678 713	13 526	582 748	15 151
Pulp mills	240 816	6 150	198 239	6 145
Nonferrous smelters	103 755	2 452	79 051	2 516
Sugar refineries	28 604	714	30 929	882
Cyanide and flotation mills	71 112	1 544	72 759	1 884
Water and sewage treatment	85 653	1 883	77 638	2 201
Uranium plants	48 866	961	56 168	1 437
Other industrial[1]	587 446	12 160	542 467	14 019
Construction				
Finishing lime	33 148	1 432	24 067	1 405
Manson's lime	26 273	802	29 369	1 040
Sand-lime brick	19 831	446	11 874	285
Agricultural	11 741	350	16 109	559
Road stabilization	8 742	238	8 463	272
Other uses	14 142	292	3 263	117
Total	1 958 842	42 950	1 733 144	47 913

Source: Statistics Canada.
[1] Includes glass works, fertilizer plants, tanneries and other miscellaneous industrial uses.
[p] Preliminary.

The new rotary kiln plant at Pavilion Lake, about 15 miles west of Cache Creek, went on stream in early 1975. It is equipped with the latest preheater design and is capable of producing approximately 300 tons a day of high-calcium lime for the mining and forestry industries in the British Columbia interior.

Summit Lime Works Limited, near Crowsnest, produces high-calcium limestone for use at sugar refineries, dolomitic and high-calcium stone for metallurgical use and high-calcium quicklime and hydrated lime for the chemical, metallurgical and construction industries.

During 1971 Texada Lime Ltd. constructed a calcimatic-kiln lime plant at Fort Langley, British Columbia capable of producing up to 200 tons a day. Limestone is barged from Texada Island, and the product — a high-calcium quicklime — is marketed throughout the mining and pulp and paper-producing regions of British Columbia. The plant went on stream in February 1972. MacDonald Consultants Ltd. of Vancouver, in partnership with M C Q Industries of Columbus, Ohio, were responsible for the design and development of the project. In late 1973 Texada Lime Ltd. was sold to Columbia Lime Products Limited.

Markets, outlook and trade

The metallurgical industry provides the largest single market for lime. With the increased application of the basic oxygen furnace (BOF) in the steel industry, lime consumption increased greatly in certain areas of the United States and Canada. An expected increase in the demand for steel will result in the need for more fluxing lime and will encourage the development of captive sources by steel producers. The pulp and paper industry is the second-largest consumer of lime, most of which is used in the preparation of digesting liquor and in pulp bleaching. Any reduction of activity in either of these two industry segments, brought on by strikes or lack of product demand, can have immediate and serious effect on the lime industry, at least regionally.

The uranium industry uses lime to control hydrogen-ion concentration during uranium extraction, to recover sodium carbonate and to neutralize waste sludge. In the production of beet sugar, lime is used to precipitate impurities from the sucrate. It is used also in the manufacture of many materials such as calcium carbide, calcium cyanamide, calcium chloride, fertilizers, insecticides, fungicides, pigments, glue, acetylene, precipitated calcium carbonate, calcium hydroxide, calcium sulphate, magnesia and magnesium metal.

The rapidly-growing concern for care and treatment of water supplies and the appeal for enforced antipollution measures should result in greater use of lime for water and sewage treatment. The removal of SO_2 from

Table 5. World production of quicklime and hydrated lime, including dead-burned dolomite sold and used, 1975-76

Country	1975^p	1976^e
	(thousand tonnes)	
U.S.S.R.	23 000^e	. .
United States	17 357	18 234
West Germany	9 175	9 525
Japan	9 172	9 525
Poland	8 000	. .
France	4 539	4 717
Belgium	3 500^e	3 629
East Germany	3 100^e	. .
Romania	3 000^e	. .
Czechoslovakia	2 800^e	. .
Chile	2 600^e	2 722
Yugoslavia	2 200^e	. .
Italy	2 186	2 268
Brazil	2 000^e	2 087
Canada	1 602	1 825
Other countries	11 402	53 433
Total	105 633	107 965

Sources: U.S. Bureau of Mines, Commodity Data Summaries, January 1977; U.S. Bureau of Mines, Mineral Trade Notes, Vol. 74, No. 1-2; and Statistics Canada.
^{p} Preliminary; ^{e} Estimated; . . Included in other countries.

hydrocarbon fuels, either during the burning procedure or from stack gases by either wet or dry scrubbing, could necessitate the use of lime and will undoubtedly develop a major market for this commodity as SO_2 emission regulations are developed. Lime is effective, inexpensive, and can be regenerated in systems where the economics would so dictate. The creation of large amounts of gypsum waste sludge during SO_2 removal will present a disposal problem. Paradoxically, the lime industry is itself caught up in the clean-up campaigns sponsored by various levels of government, particularly those efforts directed at dust removal.

Soil stabilization, especially for highways, offers a potential market for lime. However, not all soils have the physical and chemical characteristics to react properly with lime to provide a dry, impervious, cemented and stable roadbed. Hydrated lime added to asphalt hot-mix prevents the asphalt from stripping from the aggregate. This could become more important as new technologies relating to asphalt maintenance and repair are adopted and as the sources of good clean aggregate become scarce.

The use of lime-silica bricks, blocks, and slabs has not been popular in Canada as in European countries although lightweight, cellular, insulating masonry forms have many features attractive to the building construction industry.

Although quicklime and hydrated lime are not of relatively high monetary value, they are transported considerable distances in bulk or in packages if a market exists. Freight costs can represent a large part of the consumer's cost. Production costs have been significantly increased as a result of higher energy costs. The industry, on average, uses more than 5.5 million Btu's per ton of production. New plants have incorporated preheater systems, and the need to replace some of the older, less efficient production capacity with fuel-conserving equipment is well recognized. The industry is aiming at a 14 per cent improvement in fuel utilization by 1980 over the base year of 1973.

Limestones are well distributed in Canada, but it does not necessarily follow that a lime-consuming industry will produce lime for captive use — lime producers will usually offer competitive prices. Nevertheless, some major users do produce lime for their own use and, especially in the United States in recent years, iron and steel producers have integrated backwards into lime manufacture. The complexities and inconsistencies of lime production and marketing are illustrated by the fact that Domtar, a Canadian company, operates a lime plant in Tacoma, Washington and in 1975 purchased a lime plant at Bellefonte, Pennsylvania from National Gypsum Company.

Canada is a net exporter of lime.

Prices

Quoted prices for both quicklime and hydrate vary greatly throughout the country, reflecting the costs of production and the influence of nearest competition. In Ontario prices for quicklime and hydrated lime were quoted as $27.60 and $28.10 respectively, bulk, fob works, carload lots, per short ton, during 1976.

Canadian lime prices quoted in Canadian Chemical Processing of October 1976.

Lime, carloads, fob works, bulk, per short ton

Ontario, quicklime — $29.35
Ontario, hydrated — $29.85

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29010-1	Lime	free	free	25%	free

United States

Item No.			
512.11	Lime, hydrated	free	free
512.14	Lime, other	free	free

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States (Annotated), 1976, TC Publication 749.

In spite of modern technology and the growth of large cities based on mining economies, there are still many locations in Canada where mining is a frontier operation. Such a location is the Elsa "camp" of United Keno Hill Mines Ltd., some 48 kilometres from Mayo, Yukon Territory. Mount Haldane at left is an impressive backdrop for this rich silver-lead operation.

Photo courtesy United Keno

Lithium

G.H.K. PEARSE

Lithium, having a specific gravity of 0.534, is the lightest element that is solid at atmospheric temperatures. It is a soft, ductile, silvery-white metal that oxidizes rapidly in air and reacts readily with water. Lithium finds a diversity of specialized uses as mineral, industrial compound and metal. The principal ore minerals are spodumene, petalite, lepidolite and amblygonite occurring in pegmatite bodies. Lithium salts in natural brines have also become important sources of the element over the last decade.

Lithium deposits have been mined in the United States since 1889 and in Europe and Africa since the early 1900s. Lithium was used solely in a pharmaceutical preparation until near the end of the 19th century when it became important as an ingredient in special glasses. The Edison cell storage battery using lithium hydroxide was invented in 1908. Shortly after The First World War a hardened lead-base-bearing alloy containing 0.04 per cent lithium was developed in Germany. Very little further research and development was done on lithium until The Second World War. During that war, and continuing to the present, uses have multiplied dramatically, and consumption has increased more than twentyfold in the last 25 years.

Canada's only significant producer of lithium, Quebec Lithium Division of Sullivan Mining Group Ltd., near Amos, Quebec, began production in 1955. The mine was closed in 1965 in the face of a strike and reduced markets and prices. A high-grade lithium zone at Tantalum Mining Corporation of Canada Limited's mine at Bernic Lake, Manitoba is being evaluated for possible future production.

Consumption of lithium products is increasing steadily under the stimulus of aggressive research and development by major producers in the United States. However, reserves of lithium in the United States, by far the world's principal consumer, are considerable; making access to that market from outside difficult. Nevertheless, a low-iron spodumene that occurs in several Canadian deposits is of interest to ceramic manufacturers.

Occurrences, production and developments in Canada

There are five known areas in Canada where substantial reserves of lithium occur. The Val d'Or-Amos area in northwestern Quebec, in which the Quebec Lithium mine is located, has been the principal producer. Numerous spodumene-bearing pegmatites occur in northwestern Ontario, principally in the Nipigon district. Small amounts of amblygonite and lepidolite have been produced in the Winnipeg River district of southeastern Manitoba since their discovery in 1924. More recently, in that area, Tantalum Mining Corporation of Canada Limited has delineated large reserves of spodumene ore at its Bernic Lake tantalum deposit. Several deposits have been explored in the Herb Lake area of northern Manitoba.

Amblygonite was recovered from two deposits in the Yellowknife-Beaulieu district, Northwest Territories, and small shipments were made between 1945 and 1955. Deposits in this district are currently considered too remote to be of commercial interest.

Quebec. *Sullivan Mining Group Ltd., Quebec Lithium Division, Amos Mines Limited.* The Quebec Lithium property is underlain by numerous parallel pegmatite dykes trending easterly in a zone some 2 500 by 600 metres in the contact area between greenstones and granodiorite of the Lacorne batholith. Individual dykes are up to 600 metres long and 30 metres wide. Total reserves have not been made known by the company but are about 20 million tonnes*, grading 1.2 per cent Li_2O. Plant start-up was in 1955. By 1957 a throughput of 900 tonnes of ore a day was achieved; the product being shipped to the United States under contract with Lithium Corporation of America. Upon cancellation of the contract, production was temporarily suspended in 1959 and resumed, at a reduced rate of about 230 tonnes a day, in 1960 to supply the newly built lithium

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

chemical plant. A strike curtailed production in October 1965 and, in the face of dwindling markets and prices, management decided to close down operations and await more favourable developments in the industry. Stocks on hand were disposed of over the following two years. Total production from the mine was around 1 million tonnes of ore.

Other lithium properties of interest occur in the area.

Ontario. *Lithium deposits, Nipigon district.* The first spodumene pegmatite southeast of Lake Nipigon was discovered in 1955. Exploration which followed outlined several deposits with significant tonnages and grades. The principal property in the area is that of Big Nama Creek Mines Limited near Beardmore which is underlain by an *en echelon* dyke set totalling 860 metres feet in length and averaging 18 metres in width, and a parallel dyke to the south 250 by 18 metres. Diamond drilling has indicated 3.8 million tonnes grading 1.06 per cent Li_2O to a depth of 300 metres.

Development work carried out by Big Nama Creek Mines included the construction of a headframe, surface buildings, and the sinking of a shaft to 155 metres. Work was suspended in 1957. Renewed interest has been shown in the deposits by a European group, and metallurgical testing was done by Lakefield Research in 1975.

Jean Lake Lithium Mines Limited and Ontario Lithium Company Limited have outlined 1.5 million tonnes grading 1.3 per cent, and 1.8 million tonnes grading 1.09 per cent Li_2O, respectively. Other deposits of less than one million tonnes which carry values up to 2 per cent lithia occur in the district. One of these, owned by Bird River Mines Co. Ltd., has been actively explored over the last few years. Bulk sampling is reported to indicate a good grade of low-iron spodumene.

Other occurrences. Other properties of interest have been explored in northwestern Ontario; one in particular near Lac La Croix, about 100 kilometres east-southeast of Fort Frances, has an indicated 1.4 million tonnes grading 1.20 per cent lithia over a strike length of 500 metres to a depth of 150 metres.

Manitoba. *Tantalum Mining Corporation of Canada Limited, (Tanco) Bernic Lake.* Numerous complex, zoned pegmatites, bearing a variety of minerals, are known in the Cat Lake-Winnipeg River district of southeastern Manitoba. Tantalum Mining Corporation's deposit at Bernic Lake has the double distinction of being the world's largest tantalum deposit and the only known commercial deposit of pollucite, the principal source of cesium. A spodumene zone containing 4.5 million tonnes of 3 per cent Li_2O over a width of 10 metres occurs in the main pegmatite sill, and exploratory drilling underground penetrated a spodumene-bearing body beneath the present workings. The main zone is possibly the richest orebody of its kind in the world and the product is extremely low in iron and other impurities. A few tons of lepidolite were shipped from the Bernic Lake property prior to the mid-1950s.

A loan from the Manitoba Development Corporation was secured by Tantalum Mining Corporation in February 1972, for the construction of a pilot mill to produce spodumene concentrates. Trial shipments to customers during 1973 confirmed the product's suitability for ceramic purposes. In May 1974, Kawecki Berylco Industries, Inc. (KBI) of New York acquired 24.9 per cent of Tanco. KBI, a major specialty metal producer, will assist in engineering feasibility studies for lithium production. The proposed facilities include a mill which will utilize heavy media and flotation for beneficiation, and a lithium chemicals plant. Planned annual output is about 6 000 tonnes of Li_2CO_3 and a ceramic grade product of 1 000 tonnes of Li_2O equivalent (15 000 tonnes of product). A pilot lithium chemicals plant was built by KBI at Boyertown, Pennsylvania in 1975 to evaluate commercial production. Further developments await a resolution of the parent company's financial problems.

Several other occurrences in the Cat Lake-Winnipeg River district contain over 1 million tons of reserves grading 1.2 per cent or more lithia. Petalite, amblygonite and other less-common lithium minerals occur, particularly at the east end of Bernic Lake. Beryllium, tin, columbium, tantalum, rare earths and other elements occur in the pegmatites of this area.

Herb Lake district. The two principal occurrences in the Herb Lake district of northern Manitoba contain 2 to 3 million tonnes of spodumene ore grading 1.2 to 1.4 per cent Li_2O.

Northwest Territories. Many lithium-bearing pegmatites are known in the Yellowknife-Beaulieu district of the Northwest Territories. There are reserves of several tens of millions of tonnes in the district, principally of spodumene ore, but also including significant tonnages of amblygonite. The remote location and lithium market conditions preclude exploitation of these deposits at present.

Other Canadian occurrences. Lithium pegmatites are known in several localities in the Appalachians, and two occurrences are reported from the Revelstoke district in British Columbia. These are currently of mineralogical interest only.

Uses

The unique physical and chemical properties of lithium and its compounds have given rise to a diversity of uses which continue to increase. The metal is employed in metallurgical applications as an alloy constituent and as a scavenger and deoxidizer of other metals. Lithium is the most electro-positive of the elements, which, with its light weight, makes it attractive as an anode material in batteries. This application is actively being explored and, within the last few years, several promising developments have been reported. The minerals lepidolite, petalite and spodumene find use as constituents in special glasses, ceramics, enamels and as welding and brazing fluxes. Lithium chemicals are used in the manufacture of lubricating greases, as a catalyst in numerous organic chemical processes, *e.g.*, rubber and vitamin manufacture; as a dry chlorine vehicle for sanitation purposes and in pharmaceutical preparations. The use of lithium carbonate in aluminum production cells increases recovery, reduces power requirements and reduces fluorine gas emission. Growing acceptance of lithium carbonate by the aluminum industry has been the main factor in the increasing demand for lithium in recent years. Other lithium chemical applications include use in air conditioning, generation of oxygen and as an electrolyte in batteries.

World review

The United States is the world's principal producer and by far the greatest consumer of lithium products. Prior to the start of The Second World War production was about 100 tonnes of lithia (Li_2O) equivalent a year.* In 1976 world production was estimated to be 13 000 tonnes, more than two-thirds of which was produced by the United States. This represents a modest increase over last year, but output was still below that of 1974.

Table 1. United States consumption of lithium[1], 1973

	1973
	(tonnes Li_2O)
Aluminum production	2 720
Ceramics, glass	2 000
Grease	935
Air conditioning	500
Welding, brazing	700^e
Alloying, etc.	450^e
Other	240^e
Total[2]	7 550

Source: *Mineral Facts and Problems*, 1975.
[1]Figures converted to tonnes of Li_2O equivalent. [2]Total rounded.
^{e}Estimated by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

All three producers in the United States also manufacture lithium chemicals. Foote Mineral Company mines spodumene at Kings Mountain, North Carolina and recovers lithium carbonate from brines at Silver Peak, Nevada. In May 1973, Foote opened a plant at Kings Mountain to produce low-iron spodumene by its recently developed thermal process. In December 1976, the company began production at its new 5 500-tonne-a-year lithium carbonate plant at Kings Mountain. The Silver Peak operation has a capacity of 6 400 tonnes a year. Kerr-McGee Corporation (formerly American Potash and Chemical Corporation) recovers lithium carbonate from brines at Searles Lake, California. Lithium Corporation of America, a subsidiary of Gulf Resources & Chemical Corporation, mines spodumene at Bessemer City, North Carolina. Gulf's North Carolina chemical plant capacity is 12 250 tonnes of lithium carbonate a year. A proposal to recover lithium from Great Salt Lake near Ogden, Utah was abandoned.

The United States also imports lithium in the form of chemicals and minerals such as petalite and lepidolite for use in special glasses. Imports reached some 800 tonnes a year by 1967 but during the 1970s have been about 200 tonnes. Exports of contained lithia in products are about 2 000 tonnes a year.

Rhodesia was producing as much as 4 000 tonnes a year and was the primary supplier of United States import requirements until the United Nations embargo. Under this pressure, production tapered off to about 600 tonnes a year in 1972 and 1973. The sole producer, Bikita Minerals (Private) Ltd., is reported to have closed its mine in 1974, making some shipments from stocks the following year.

Other major producers include the U.S.S.R., the People's Republic of China and Namibia (formerly Southwest Africa). The U.S.S.R. is thought to have

Table 2. World lithium production, 1974-76

	1974^e	1975^e	1976^e
	(tonnes Li_2O)		
United States	10 400	9 700	10 000
Argentina	10	10	10
Brazil	300	150	200
People's Republic of China	650	550	550
Portugal	34	42	41
Namibia	100	90	90
Rhodesia	200	—	—
U.S.S.R.	2 300	2 300	2 300
Total[1]	14 000	12 800	13 000

Sources: Various, including U.S. Bureau of Mines Commodity Data Summaries, Estatisticas Industriais (Portugal) and estimates by the Mineral Development Sector, Department of Energy, Mines and Resources. The latter includes the United States, Brazil, Namibia, Rhodesia and the U.S.S.R.
[1]Total rounded. ^{e}Estimated; — Nil.

*Production and consumption figures given are metric tons of Li_2O equivalent, except where otherwise indicated.
These figures can be converted to lithium metal equivalent by dividing by 2.153. Lithium carbonate figures can be converted to lithium metal equivalent by dividing by 5.323.

increased domestic consumption sharply over the last few years, especially for aluminum production. Approximately half of that country's total annual exports of an estimated 1 450 tonnes to the western world was shipped to Japan during the early 1970s and most of the remainder to Western Europe. Soft market conditions have resulted in considerable reduction of U.S.S.R. exports in the last few years.

Chile may become an important producer of lithium from the Salar de Atacoma, a brine deposit being evaluated by Foote Mineral Company.

The lithium chemicals industry in Europe relies wholly on raw material imports. In recent years, Rhône-Poulenc Establissements Tricot in France, Montecatini, S.A. in Italy and Associated Lead in England closed their lithium chemicals plants leaving Metallgesellschaft A.G. as the sole producer in Europe.

World reserves of lithium were estimated by the United States Bureau of Mines in 1974 to be about 2.0 million tonnes of contained lithium (4.4 million tonnes Li_2O), 370 000 tonnes of which occur in the United States. Total world reserves are more than adequate to meet anticipated requirements well into the 21st century.

Canada's reserves are estimated by the Department of Energy, Mines and Resources to be about 400 000 tonnes of contained lithium.

Outlook

The lithium industry is small in comparison with other segments of the mining and chemical industries. However, it has grown steadily since the end of The Second World War and continued growth at moderate rates is assured for the long term. Annual consumption of lithium in the United States by the year 2000 is estimated to be between 16 000 and 60 000 tonnes Li_2O based on projections made by the U.S. Bureau of Mines in 1975 (its figures are given as 8 220 and 30 780 short tons lithium metal equivalent).

Several breakthroughs in battery technology have been announced and the potential for battery use as a power source for automobiles and for peak power generation has become evident. One estimate for peak power installation requirements is an initial 4 900 tonnes of lithia. Annual requirements for electric automobiles could reach 30 000 tonnes by the turn of the century. World energy requirements will have to be met ultimately by thermonuclear reactors, the simplest form of which would utilize lithium, both as a heat transfer medium and a source of tritium for the reaction. The first practical plant is unlikely to be constructed until after the end of the century, but research requirements in this area may well expand significantly before that. The surge of lithium consumption in the United States during the 1950s, which peaked in 1959, was undoubtedly due to procurements for thermonuclear research. Consumption figures for this purpose are kept secret, but an estimate of 7 000 tonnes between 1953 and 1959 seems likely. Fusion research uses may, therefore, easily exceed 1 000 tonnes a year during the 1990s. Given these developments, consumption in the United States could well reach 50 000 tonnes a year by the year 2000.

During 1974 world lithium supplies were tight as a result of reduced exports from the U.S.S.R., closure of Bikita Minerals (Private) Ltd.'s mine in Rhodesia and increased demand in aluminum production. During 1975 demand dropped about 10 per cent. In 1976 there was little change from the previous year as world economies remained soft. Despite softened markets for aluminum, consumption of lithium in this industry should continue to increase as its use becomes more general. The availability of large reserves, principally in the United States and Canada, ensures adequate lithium for the greatly expanded requirements expected over the balance of this century.

Magnesium

M.J. GAUVIN

Magnesium is found in naturally-occurring rocks and minerals such as dolomite, magnesite, brucite and olivine; in seawater, brines and evaporite deposits, and is consumed mostly in the form of nonmetallic compounds, principally magnesium refractories. Metal represents only about 10 per cent of consumption on a magnesium-content basis.

The metal is produced by two basic processes. The first is by electrolysis of magnesium chloride derived from seawater and brines. The second is a silicothermic process whereby magnesium ore, such as dolomite or magnesite, is mixed with ferrosilicon and reduced at high temperatures. All Canadian production is by the latter method, which is more suitable for smaller plants. The electrolytic method has risen to prominence because of large-scale plants utilizing low-cost electric power. Power requirements to produce magnesium electrolytically are 8 to 9 kWh per pound, even higher than the 7 to 8 kWh required to produce a pound of aluminum by the conventional Hall-Heroult process, and considerably higher than for the silicothermic process, including production of the ferrosilicon.

Canada

The only Canadian producer of primary magnesium is Chromasco Limited. This company has operated a mine and smelter at Haley, Ontario, 80 kilometres west of Ottawa, since 1942.

A high-quality (98 per cent pure) dolomite, low in impurities such as silica and the alkali metals, is mined from an open pit and calcined in a rotary kiln to produce dolime. Using the silicothermic (Pidgeon) process, dolime is mixed with ferrosilicon at a ratio of about 5 to 1. This mixture is charged in batches into retorts which are externally heated in furnaces, using natural gas as the main fuel. Under vacuum and at high temperature, the magnesium content is reduced and accumulated as crystalline rings known as "crowns" in the water-cooled head sections of the retorts. The plant has an annual capacity of 10 800 tonnes* of magnesium metal. It was operating well below capacity at the beginning of 1976, but production increased steadily during the year until the facility was operating at full capacity by year-end. Part of the furnace capacity of the plant is used to produce calcium and strontium.

The company produces ingots of magnesium metal in the following grades and purities: commercial, 99.90 per cent; high purity, 99.95 per cent; and refined, 99.98 per cent. Magnesium alloys are produced to all specifications. Other magnesium products include master alloys, rods, bars, wire and structural shapes. The Pidgeon process is particularly suited for production of the purer forms.

To produce commercial-grade magnesium, the crowns are simply remelted and cast into ingots. This grade is suitable for general fabrication purposes and for alloying with aluminum, and represents the major share of production. The high-purity grade is mostly used for the formation of Grignard reagents (alkyl-magnesium-halides which react to form a variety of organic and inorganic compounds). The refined grade is in demand for chemical laboratory use, and as a reducing agent for titanium, zirconium, uranium and beryllium.

Production of magnesium in 1976 was 5 858 tonnes valued at $12 248 000, compared with 3 826 tonnes in 1975 valued at $8 788 248. In 1976 domestic consumption of magnesium was 4 230 tonnes, a sharp decrease from the 5 404 tonnes consumed in 1975. The aluminum alloy industry was the predominant outlet for magnesium, with the casting industry the next-largest consumer of the metal.

Imports of magnesium metal and alloys were 1 709 tonnes in 1976, compared with the 8 385 tonnes imported in 1975. Exports of 3 226 tonnes of Canadian magnesium in 1976 were down from the 3 766 tonnes

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

exported in 1975. Exports of magnesium metal have entered the United States duty free under the Canada-United States Defence Production Sharing Program which has recently been operating on a small scale. In the form of ingots, the United States tariff on magnesium is 20 per cent, whereas the comparable Canadian tariff is 5 per cent. Only in certain highly-pure items can the Candian product find a market, except under the Defence Production Sharing Program, or if the customer has a duty-drawback because of reexport.

Table 1. Canada, magnesium production and trade, 1975-76

	1975		1976ᵖ	
	(tonnes)	($)	(tonnes)	($)
Production[1] (metal)	3 826	8 788 248	5 858	12 248 000
Imports				
Magnesium metal				
United States	5 587	10 361 000	1 052	2 123 000
Brazil	—	—	55	93 000
Norway	—	—	19	45 000
Netherlands	1 297	2 403 000	—	—
United Kingdom	103	192 000	—	—
Denmark	10	28 000	—	—
Other countries	502	1 014 000	—	—
Total	7 499	13 998 000	1 126	2 261 000
Magnesium alloy				
United States	470	1 192 000	581	1 442 000
United Kingdom	99	341 000	84	333 000
Australia	—	—	17	71 000
Switzerland	39	87 000	1	1 000
Other countries	278	536 000	—	—
Total	886	2 156 000	683	1 847 000
Exports				
United Kingdom	1 495	3 351 000	1 108	2 376 000
United States	1 606	4 273 000	625	1 849 000
Netherlands	265	511 000	432	749 000
West Germany	29	54 000	348	604 000
France	90	208 000	217	473 000
Argentina	1	9 000	142	247 000
Switzerland	107	237 000	88	186 000
Spain	—	—	79	139 000
Australia	7	22 000	42	125 000
Israel	43	151 000	25	76 000
India	20	54 000	34	74 000
Japan	—	—	25	69 000
Turkey	9	16 000	22	44 000
South Korea	—	—	22	40 000
Brazil	10	43 000	10	21 000
Uruguay	2	14 000	3	14 000
Colombia	—	—	2	8 000
Greece	—	—	1	7 000
Hong Kong	—	—	1	3 000
Other countries	82	176 000	—	—
Total	3 766	9 119 000	3 226	7 104 000

Source: Statistics Canada.
[1]Magnesium metal in all forms and in magnesium alloys produced for shipment, less remelt.
ᵖPreliminary; — Nil.

World review

World production of primary magnesium in 1976 is estimated at 244 200 tonnes, compared with 258 300 in 1975. The United States produced almost half of the world's output, followed by the U.S.S.R. and Norway.

Since 1962 noncommunist world consumption has exceeded production. The market has been held in balance by sales from the United States government stockpile and exports for the U.S.S.R. During 1974 the General Service Administration completed the disposal of all magnesium metal in the government stockpile. During the recession years of 1975 and 1976 world production exceeded demand, and industry is adding to capacity to supply the anticipated increase in world demand.

The world's largest producer is The Dow Chemical Company in the United States. Its plant at Freeport, Texas produces magnesium metal from seawater and has a capacity of 110 000 tonnes a year. Dow is expanding the capacity of this plant to 127 000 tonnes, with completion scheduled by 1980. The company has also announced plans to construct a new plant with a capacity of 45 000 tonnes of magnesium metal a year.

N L Industries, Inc. started production from lake brines at its Rowley, Utah plant in 1972. The plant has a designed capacity of 40 800 tonnes a year. It has been plagued with technical problems and in the last quarter of 1975 production was curtailed except for purposes of technical evaluation. All production was stopped in April 1976 and facility modifications to provide the necessary improvements were begun. Production is scheduled to re-start in 1977 and reach an annual rate of 22 500 tonnes by the end of the year. A second phase of equipment additions will further increase plant capacity.

The electrolytic plant of American Magnesium Company at Snyder, Texas, has a capacity of 9 000 tonnes a year. The company is expanding its facility to 27 000 tonnes a year and the work is expected to be completed by 1980.

Northwest Alloys, Inc., a subsidiary of the Aluminum Company of America (Alcoa) brought its Addy, Washington magnesium plant into production during the year with an initial capacity of 21 700 tonnes and the company plans to increase capacity to 36 000 tonnes in 1980. The magnesium output is used in alloying by Alcoa. Ferrosilicon is also produced at the plant for use by Alcoa and other metal producers.

In Norway, Norsk Hydro-Elektrisk Kvaelstofaktieselskab will begin construction in 1978 of a 100 000-tonne-a-year magnesium plant in Mongstad, Norway which will use Norsk Hydro's new process for producing anhydrous magnesium chloride from a brine base. The $200-million plant is scheduled for completion in 1981. In Yugoslavia, a 5 000-tonne-a-year magnesium plant will be built at Bela Stena which will use the Pechiney Ugine Kuhlman Development, Inc. Magnotherm process.

Technology

Technology is playing a large role in the growth of the magnesium industry. In fluxless melting, a heavy inert gas, sulphur hexafluoride (SF_6), to prevent melted magnesium from oxidizing, is used as a flux. The development of an efficient method to produce anhydrous magnesium chloride provides a feed for the electrolysis stage which results in a high-purity magnesium with less energy requirements, and also produces a chlorine as a valuable byproduct. Upgrading of current magnesium-producing facilities is expected to result in an energy saving of 25 per cent. The development of hot-chamber die-casting technology is increasing the demand for magnesium. Developed and first used in Europe, machines employing this technology are now being used in North America, together with an inert atmosphere for the casting of small parts, especially those having shapes that are difficult to cast. The use of magnesium in the desulphurization of blast furnace iron is a recent development showing major promise.

Table 2. Canada, magnesium production, trade and consumption, 1965, 1970 and 1974-76

	Production[1] Metal	Imports Alloys	Imports Metal	Exports Metal	Exports Metal	Consumption[2] Metal
	(tonnes)	(tonnes)	(tonnes)	(tonnes)	($)	(tonnes)
1965	9 169	150	1 488	..	4 456 255	4 081
1970	9 392	232	1 847	6 957	5 562 000	4 478
1974	5 956	734	6 748	3 237	5 960 000	6 216
1975	3 826	886	7 499	3 766	9 119 000	5 404[r]
1976[p]	5 858	683	1 127	3 226	7 104 000	4 230

Source: Statistics Canada.
[1]Magnesium metal in all forms and in magnesium alloys produced for shipments, less remelt; [2] Consumption as reported by consumers.
[p]Preliminary; .. Not available; [r]Revised.

Table 3. Canada, consumption of magnesium, 1965, 1970 and 1974-76

	1965	1970	1974	1975	1976^p
			(tonnes)		
Castings[1]	464	771	1 163	960	610
Extrusions[2]	507	429	185	341	477
Aluminum alloys	2 684	2 833	3 606	2 918^r	2 073
Other uses[3]	424	444	1 260	1 185	1 070
Total	4 079	4 477	6 214	5 404^r	4 230

Source: Statistics Canada.
[1]Die, permanent mould and sand; [2]Structural shapes, tubing, forgings, sheet and plate; [3]Cathodic protection, reducing agents, deoxidizers and other alloys.
^{p}Preliminary; ^{r}Revised.

Uses

The major use of magnesium is in aluminum alloys where it provides hardness and strength. More magnesium is utilized in aluminum alloys than in magnesium alloys. Because of its high strength-to-weight ratio, magnesium is used in structural applications; i.e., those which involve load-carrying components. Although magnesium weighs only two-thirds as much as aluminum, the latter metal can be substituted for magnesium in most structural applications, and magnesium's higher price has often placed it at a disadvantage.

Typical structural uses of magnesium are in aircraft (particularly helicopters), missiles and space exploration vehicles, luggage frames, and materials-handling equipment such as gravity conveyors and hand trucks. Magnesium castings are used extensively in power lawnmowers, chainsaws, typewriters and electronic equipment.

Non-structural applications, which have grown more quickly than structural uses, account for about 75 per cent of the consumption of magnesium. A rapidly-growing sector of this market is aluminum alloy beverage cans which contain about 2.5 per cent magnesium. Other important non-structural uses of magnesium are as an alloying element for ductile iron, as a reducing agent in the production of titanium, for cathodic protection, in the chemical industry for Grignard reagents, and as an anti-knock fuel additive.

While the present usage of magnesium as a desulphurizer in the manufacturing of steel is low, it is expected to grow rapidly and could become second only to its use in aluminum alloying.

Prices

The Canadian price of commercial-grade magnesium, carload lots, fob Haley, Ontario was 84 cents a pound at the beginning of the year. After two price increases, the quoted price in July was 92 cents, which price was maintained for the balance of the year.

In the United States, the price per pound in 10 000-pound lots of 99.8 per cent metal, fob Freeport, Texas was 82 cents (U.S.) a pound at the end of 1975. It was raised to 87 cents on January 1 and to 92 cents a pound July 1. The price of die-casting alloy AZ 91B was quoted in the United States at 89 cents (U.S.) at the beginning of the year and was raised to 94 cents on July 1.

Table 4. World primary magnesium production, 1966, 1975 and 1976

	1966	1975	1976^e
	(thousands of tonnes)		
United States	72.3	122.0^e	116.0^e
U.S.S.R.	32.7	66.0	62.0
Norway	27.5	42.2	38.0
Japan	3.8	9.0	8.0
France	3.4	8.3	7.0
Canada	6.2	3.8	5.0
Other noncommunist countries	12.1	6.0	6.0
Other communist countries	0.9	1.0	2.0
Total	158.9	258.3	244.2

Sources: Statistics Canada; U.S. Bureau of Mines; American Bureau of Metal Statistics Inc.; *Metals Week*.
^{e}Estimated.

Outlook

Aluminum alloying is expected to continue to be magnesium's most important market. Continued increased usage of beverage cans and the demand for lighter weight, fuel-saving transportation vehicles are major applications for the growth of aluminum-magnesium alloys. The use of magnesium in the desulphurization of steel is an application showing major promise and it is expected to increase rapidly. Traditional producers of magnesium are expanding to meet the anticipated increase in world demand.

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Table 5. Estimated world primary magnesium capacity 1975

	Company	Location	Annual Capacity
			(tonnes)
Canada	Chromasco Limited	Haley, Ontario	10 900 (F)
France	Société Générale du Magnesium (Pechiney Group)	Marignac	9 000 (F)
Italy	Societe Italiana per il Magnesio e Leghe di Magnesio, Milan	Bolzano	10 900 (F)
Japan	Furukawa Magnesium Company	Koyama	6 500 (F)
	Ube Kosan K K	Yamaguchi	6 500 (F)
Norway	Norsk Hydro-Elektrisk Kvaelstofaktieselskab	Heroya, near Porsgrunn	43 500 (E)
United States	The Dow Chemical Company	Freeport, Texas	110 000 (E)
	N L Industries, Inc.	Rowley, Utah	40 000 (E)
	American Magnesium Company	Snyder, Texas	9 000 (E)
	Northwest Alloys, Inc.	Addy, Washington	21 700 (F)
U.S.S.R.	Various		65 000[e] (E)

Source: Société française de minerais & métaux, and various other sources. Process: (F) Ferrosilicon; (E) Electrolytic.
[e] Estimated.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
35105-1	Magnesium metal, not including alloys, in lumps, powders, ingots or blocks	5	5	25	3
34910-1	Alloys of magnesium, ingots, pigs, sheets, plates, strips, bars, rods and tubes	5	5	25	3
34915-1	Magnesium scrap	free	free	free	free
34920-1	Sheet or plate, of magnesium or alloys of magnesium, plain, corrugated, pebbled, or with a raised surface pattern, for use in Canadian manufactures (expires 31 October 1977)	free	free	25	free
34925-1	Extruded tubing, of magnesium or alloys of magnesium, having an outside diameter of five inches or more, for use in Canadian manufactures (expires 28 February, 1978)	free	free	25	free

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Japan	Furukawa Magnesium Company	Koyama	6 500 (F)
	Ube Kosan K K	Yamaguchi	6 500 (F)
Norway	Norsk Hydro-Elektrisk Kvaelstofaktieselskab	Heroya, near Porsgrunn	43 500 (E)
United States	The Dow Chemical Company	Freeport, Texas	110 000 (E)
	N L Industries, Inc.	Rowley, Utah	40 000 (E)
	American Magnesium Company	Snyder, Texas	9 000 (E)
	Northwest Alloys, Inc.	Addy, Washington	21 700 (F)
U.S.S.R.	Various		65 000[e] (E)

Source: Société française de minerais & métaux, and various other sources. Process: (F) Ferrosilicon; (E) Electrolytic.
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34925-1	Extruded tubing, of magnesium or alloys of magnesium, having an outside diameter of five inches or more, for use in Canadian manufactures (expires 28 February, 1978)	free	free	25	free

United States

Item No.		On and After January 1 1971	1972
628.55	Magnesium, unwrought, other than alloys; and waste and scrap (duty on waste and scrap suspended to June 30, 1973)	24%	20%
628.57	Magnesium, unwrought alloys, per lb on Mg content	9.5¢ + 4.5%	8¢ + 4%
628.59	Magnesium metal, wrought, per lb on Mg content	8¢ + 4%	6.5¢ + 3.5%

Sources: For Canada, the Customs Tariff and Amendments, Revenue Canada, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), TC Publication 749.

Manganese

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As in past years, no manganese ore was produced in Canada during 1976. Two Canadian companies producing ferromanganese for use in steel manufacture used imported ore, 75 per cent of which came from Gabon and Brazil. Steel production was buoyant at the beginning of 1976, creating a strong demand for manganese but in the latter part of the year demand for steel fell due to a slump in the construction industry, and producers of ferromanganese balked at paying higher prices for manganese ore to be delivered in 1977.

Canada

Canada does not have deposits of manganese which can be considered economic, given the present state of technology and under present market conditions. Several low-grade manganese deposits have been identified in Nova Scotia, New Brunswick and British Columbia. A deposit near Woodstock, New Brunswick is Canada's largest known manganese deposit, containing 45 million tonnes* grading 11 per cent manganese and 14 per cent iron. While research has developed techniques to utilize the low-grade deposits, manganese cannot be produced in Canada at a price competitive with high grade deposits in other countries.

Two ferroalloy producers in Canada import metallurgical-grade manganese ore to make ferromanganese: Union Carbide Canada Limited (UCC) and Chromasco Limited, each having a plant at Beauharnois, Quebec, producing principally for the domestic market. Canada also imports manganese metal, an important additive in specialty steels as well as in aluminum alloys. The main consumers include Atlas Steels Division of Rio Algom Limited, the Aluminum Company of Canada, Limited (Alcan) and Reynolds Aluminum Company of Canada Ltd. High-purity manganese dioxide and battery-grade manganese ores are imported by several companies, including Mallory Battery Company of Canada Limited, Cerlite Burgess, Ray-O-Vac Division of ESB Canada Limited, Cominco Ltd. and Canadian Electrolytic Zinc Limited.

*The term refers to the metric ton of 2 204.62 pounds avoirdupois.

World production and trade

The world-wide downturn in steel production during the last half of 1975 resulted in manganese production in 1976 being significantly lower than that in 1975. However, several important developments did occur during 1976.

In Australia the Groote Eylandt Mining Company Proprietary Ltd., a wholly-owned subsidiary of The Broken Hill Proprietary Company Limited (B.H.P.), completed an expansion early in the year at its mine on Groote Eylandt in the Gulf of Carpentaria. With this expansion, output from the mine has increased from the initial production rate of 200 000 tonnes a year of metallurgical-grade ore to 2 000 000 tonnes a year in less than 10 years.

Associated Manganese Mines of S.A. Ltd. expects to replace the depleted Adamo mine with its new Gloria mine in 1977. Anglo American Corporation of South Africa Ltd. announced plans during 1976 to develop an underground manganese mine at Middleplaats, 88 kilometres northwest of Kuruman, with production scheduled to start in 1979. The ore is approximately 396 metres underground and grades approximately 38 per cent Mn. In past years, South African manganese producers have been plagued with insufficient port facilities at Port Elizabeth and Durban, resulting in severe port congestion and long shipping delays. Two new ports, one at Richards Bay on the east coast and the other at Saldarha Bay on the west coast, are currently under construction and will allow a threefold increase in export volume.

In Brazil, the state-owned companies Companhia Vale Do Rio Doce (CVRD) and Cia Matogrossense de Mineracao, and the private Alcinda Vieira group announced that they will jointly reopen the former United States Steel Corporation operation at Urucum in the state of Mato Grosso. Although the deposit contains an estimated 100 million tonnes of ore, production will only be from 50 to 80 thousand tonnes per year. The low production-to-reserve ratio is accounted

Table 1. Canada, manganese trade and consumption, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Imports				
Manganese in ores and concentrates[1]				
Gabon	37 526	5 254 000	53 424	7 768 000
Brazil	15 532	2 495 000	33 054	4 501 000
South Africa	—	—	19 463	1 832 000
Angola	—	—	7 846	982 000
Other countries	16 715	2 355 000	5 185	905 000
Total	69 773	10 104 000	118 972	15 988 000
Manganese metal				
South Africa	4 912	3 689 000	6 295	5 264 000
Japan	136	206 000	152	132 000
United States	182	251 000	104	110 000
West Germany	150	303 000	2	1 000
France	10	19 000	—	—
Total	5 390	4 468 000	6 553	5 507 000
Ferromanganese including spiegeleisen[2]				
Norway	5 173	1 435 000	6 006	3 194 000
South Africa	5 087	2 857 000	7 881	3 099 000
United States	18 706	9 271 000	6 064	2 719 000
Other countries	6 735	3 057 000	5 103	2 658 000
Total	35 701	16 620 000	25 054	11 670 000
Silicomanganese including silicospiegeleisen[2]				
United States	5 732	3 230 000	4 950	2 583 000
Norway	—	—	3 588	2 013 000
Brazil	—	—	2 064	949 000
Other countries	—	—	1 420	705 000
Total	5 732	3 230 000	12 022	6 250 000
Exports				
Ferromanganese[2]				
United States	1 097	210 000	9 799	4 003 000
Jamaica	71	33 000	62	36 000
Total	1 168	243 000	9 861	4 039 000
Consumption				
Manganese ore				
Metallurgical grade	158 556	. .	236 411	. .
Battery and chemical grade	2 420	. .	2 219	. .
Total	160 976	. .	238 629	. .

Source: Statistics Canada.
[1]Mn content; [2]Gross weight
[p]Preliminary; — Nil; . . Not available

one company doubled consumption (stocks decreased) for by the remote location of the Urucum deposit and the fact that the ore contains high levels of undesirable phosphorous and alkali metals. Industria e Comercio de Minerais S.A. (ICOMI) continued to export at the maximum level permitted by the government, 1.2 million tonnes per year, from its Amapa mine. In 1976 more than 30 million tonnes of manganese reserves had been discovered in the huge Carajas iron ore field. Total Brazilian manganese ore reserves are currently estimated at 250 million tonnes.

India maintained its export ban on high-grade manganese ores (plus 48 per cent Mn) throughout the year. Total medium and low-grade manganese ore exported during fiscal 1976 amounted to 700 000 tonnes, down 10 per cent from the previous year. It is expected that there will be a further decrease in 1977.

Minera Autlan of Mexico began production of manganese alloy from two furnaces with a combined capacity of 120 000 tonnes per year and a third furnace is planned for operation in 1979. Minera Autlan, the only North American alloyer to have a captive manganese mine, plans to double mine output during the next two years to 800 000 tonnes of manganese (40 per cent MnO) annually.

In Gabon, production of manganese ore is expected to double with the completion of the Trans Gabon railway in 1980. The railway will join the interior mining areas to the port of Libreville. The railway project also includes construction of a new port at Santa Clara, about 20 kilometres north of Libreville. Present transportation of manganese ore from the interior is by an aerial cableway, from Moanda to Mbinda in the Republic of Congo, and then by rail to Pointe Noire. The capacity of the cableway is the limiting factor in the production of Gabonese manganese ore.

In the United States, as in past years, there was no production of manganese ore during 1976. The downturn in steel production during the last half of the year caused ferromanganese producers to cut production and to stockpile delivered ore. With large stocks of ore on hand, ferromanganese producers delayed signing ore contracts for delivery in the following year. Imports of ore were down 16.4 per cent for the year. Imports of foreign-produced ferromanganese increased 31 per cent and for the first time captured more than one half of the U.S. market.

In the U.S.S.R. three new mines with a combined output of 600 000 tonnes a year commenced operations in the Chiatura region of Georgia. Manganese ore production is expected to increase to 2.7 million tonnes per year by 1980.

In Brief

Saudi Arabia. Plans for a ferromanganese plant, for which Australia's B.H.P. has completed a feasibility study, stalled due to reorganization of the government.

Upper Volta. A five-country, 14-company consortium is still developing plans to produce from the 14-million-tonne, high-grade manganese deposit at Tambao.

Zaire. Exports of manganese from Zaire have been completely halted by the closure of the Benguela railroad which passes through Angola. Until other routes become economical, the state-owned Soc. Minière de Kisenge is stockpiling ore.

Uses

The excellence of manganese as a desulphurizer makes it irreplaceable in the steel industry. Steels containing excess sulphur are not homogeneous and tend to crack and tear during rolling and forming. Added manganese combines with the sulphur and produces a manganese sulphide slag which is readily separated from the steel. Manganese also acts as a deoxidizer during the manufacture of steel.

Manganese is usually added as a ferroalloy during the making of steel. The principal manganese ferroalloys are shown in Table 4. Steel manufacturers in Canada add about 5.8 kilograms of manganese per tonne of crude steel produced.

Manganese is often added to specialty steels to increase strength and hardness. Manganese metal, instead of ferromanganese, is used in making these specialty steels because it provides better control of the manganese content and the level of impurities.

The Hadfield steels, a type of specialty steel, contain between 10 and 14 per cent manganese. They are extremely hard and tough and are suited to applications where severe mechanical conditions are encountered, such as in rock crusher parts, or in the teeth of earth-moving machinery.

Iron castings often contain an appreciable amount of manganese, which has been added to remove excess sulphur. Sulphur causes surface imperfections as well as making precise casting very difficult.

Manganese is also alloyed with nonferrous metals. Aluminum-manganese alloys are noted for their strength, hardness and stiffness; manganese-magnesium alloys are hard, stiff and corrosion-resistant; and manganese-bronzes are used in the production of ship's propellers.

Manganese also has a wide variety of non-metallurgical uses. The most important is as manganese dioxide in dry cell batteries, where it is used for its readily available oxygen rather than for its manganese. Hydrogen produced during the cell activity slows the actions, while oxygen from the manganese dioxide combines with the hydrogen to allow the battery to operate at its maximum efficiencies. Manganese ores used in batteries must grade above 85 per cent manganese dioxide and must have a low iron content. Since very few natural manganese dioxide ores are satisfactory for battery purposes, most batteries contain a blend of natural ore and synthetic manganese dioxide.

Table 2. Canada, manganese imports, exports and consumption, 1965, 1970, 1974-76

	Imports			Exports	Consumption	
	Manganese Ore[1]	Ferro-manganese	Silico-manganese	Ferro-manganese	Ore	Ferromanganese and Silicomanganese
	(gross weight, tonnes)					
	259.40	441.19	441.60	441.19		
1965	81 175	31 354	714	3 463	108 217	70 186
1970	115 052	17 891	975	510	153 846	97 952
1974	125 103	17 114	542	10 247	210 595	94 726
1975	69 773	35 701	5 732	1 168	160 976	95 869
1976[p]	118 972	25 054	12 022	9 861	. .	. .

Source: Statistics Canada.
[1]Mn content.
[p]Preliminary; . .Not available.

Table 3. World production of manganese ores

	Mn[e]	1973	1974	1975[p]
	(per cent)	(thousands of tonnes)		
U.S.S.R.	35	8 245	8 500	8 800
Republic of South Africa	30+	4 176	4 745	5 769
Gabon	50-53	1 919	2 064	2 230
Brazil	38-50	1 615	1 789	1 630[e]
Australia	37-53	1 522	1 522	1 555
India	10-54	1 489	1 447	1 531
People's Republic of China	30+	1 000[e]	1 000[e]	1 000[e]
Mexico	35+	364	403	428
Ghana	32-50+	318	250	415
Zaire	35-55	334	288	309
Hungary	30−	188	134	182
Japan	27-45	189	167	158
Morocco	53	146	175	131
New Hebrides	42-44	30	47	46
Iran	33+	22	30	36
Bulgaria	30−	38	34	35[e]
Argentina	27-30	12	26	31
Other countries[1]		140	122	113
Total		21 747	22 743	24 399

Source: U.S. Bureau of Mines, *Mineral Industry Surveys,* December, 1976; *Minerals Yearbook* Preprint, 1974.
[1]Includes 19 countries, each producing less than 31 000 tonnes per year.
[p]Preliminary; [e]Estimated.

Following is the normal classification of manganese ore:

Manganese ores contain more than 35 per cent manganese and are used in the manufacture of both low- and high-grade ferromanganese. Battery-grade ores are included in this class; however, battery-grade ores must contain no less than 85 per cent manganese dioxide.

Ferrogenous manganese ores contain 10 to 35 per cent manganese and are used for the manufacture of spiegeleisen. *Manganiferous iron ores* contain 5 to 10 per cent manganese and are used to produce manganiferous pig iron.

All types of manganese ores including manganese dioxide ores are used in the production of manganese chemicals such as: potassium permanganate, a powerful oxidant used in the purification of public water supplies; manganous oxide, an important addition to welding rods and fluxes; and an organometallic form of manganese which inhibits smoke formation and improves combustion of fuel oil.

A number of manganese chemicals are employed to produce various colour effects in face bricks and, to a lesser extent, to colour or decolour glass and ceramics. They are also used as paint and varnish driers and in the production of dyes, fungicides and pharmaceuticals.

Prices

An interesting development that bears watching is the emergence of Japanese ore negotiations as a focal point in establishing world-wide contract price levels. In the past, the first delivery contract signed by a European consumer for a boatload of ore usually set the price for the remaining annual contracts. Another factor which has begun to affect ore prices is the increasing trend of mining companies and their governments to set minimum acceptable ore prices. Formerly a producers' agent, usually a world-wide metal trading company, was influential in setting contract prices.

Table 4. Principal manganese ferroalloys

	Manganese	Silicon	Carbon
		(per cent)	
Ferromanganese			
High-carbon	74-82	1.25 max	7.5 max
Medium-carbon	74-85	1.50 max	1.5 max
Low-carbon	80-85	7.00 max	0.75 max
Silicomanganese	65-68	18-20 max	0.6-3.0
Spiegeleisen	16-28	1.0-4.5	0.65 max

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

Manganese nodules

Manganese nodules are formed by the accretion of manganese and iron oxides, along with other detrital mineral, around some kind of nucleus. The most common detrital minerals include nickel, copper and cobalt. The nodules are found in both marine and freshwater environments. They are generally 2 to 10 centimetres in diameter, often spherical or lens-shaped, have a wet density (water saturated) of about 2.0 g/cm^3, and are very porous, containing about 30 per cent water by weight.

Manganese nodules have been of commercial interest since 1959, when it was suggested that the nodules offered potential as an ore of copper, nickel, cobalt and manganese. Nodule deposits are two-dimensional orebodies having width and length but being only a

Table 5. The three major consortia involved in seabed mining

Consortium	Companies
1. Ocean Mining Associates	United States Steel Corporation, U.S.A. Union Minière S.A., Belgium Deepsea Ventures Inc. (contracted)
2. Kennecott Joint Venture	Kennecott Copper Corporation (50%) U.S.A. Noranda Mines Limited (10%) Canada Mitsubishi Corporation (10%) Japan Rio Tinto Zinc Group Ltd. (10%) U.K. British Petroleum Company Limited (10%) U.K.
3. Ocean Management Inc.	Inco Limited (25%) Canada Arbeitsgemeinschaft Meerestechnische gewinnbare Rohstoff (25%) W. Germany SEDCO, Inc. (25%) U.S.A. Deep Ocean Mining Company (25%) Japan

single layer thick. The deposits occur at or near the sea floor-water interface and exhibit extreme changes in abundance over short distances.

Private industries are concerned with recovering the manganese nodules for their nickel and copper content. Nodules which contain economic amounts of nickel and copper are found only at depths greater than 3000 metres, and more commonly around 4000 to 5000 metres. In 1974 and 1975 three major consortia were formed for the exploitation of the nodules. Each consortia includes at least one company which has been involved in the research and development of ocean mining techniques. The consortia evolved mainly because of the high capital costs and high-risks involved in the early development and actual mining stages.

Although all consortia are progressing as well as can reasonably be expected, most have reached the point where either technological or economic success is certain. Actual seabed mining, however, is still many years away.

Outlook

The year 1976 did not turn out to be the recovery year for the economy that was expected. In the latter months manganese demand fell as the anticipated steel recovery did not materialize. Ferromanganese producers stockpiled excess ore stocks and were reluctant to sign new contracts at higher prices.

The short-term outlook is for an increase of about 3 to 4 per cent in manganese ore prices; however, allowing for inflation, the real ore price will have declined for the third consecutive year.

In the long-term there is the possibility of a decrease of 25 per cent in demand for manganese. A process of external desulphurization of steel, although still in the experimental stage, will have a direct effect on the consumption of manganese used in making steel. Other changes in steel technology such as the trend from open hearth furnaces to the basic oxygen furances, and the continuous casting of steel, are expected to reduce the amount of manganese per ton of steel by 10 to 30 per cent.

The lower growth rate in world steel production, which accounts for 95 per cent of the manganese consumed, will ultimately affect the manganese outlook. Recent projections indicate a 3 per cent growth rate in world steel production to the year 2000. This is down 0.5 to 1.0 per cent from the previous projection, and indicates a lower growth rate in manganese production.

United States prices in U.S. currency, published by Metals Week of December 1975 and December 1976

	December 1975	December 1976
	(¢)	(¢)
Manganese ore, per long-ton unit (22.4 lb) cif U.S. ports, Mn content		
Min. 48% Mn (low impurities)	138.0 — 142.0	147.0 — 153.0
Ferromanganese, fob shipping point, freight equalized to nearestmain producer, carload lots, lump, bulk	($)	($)
Standard 78% Mn, per long-ton unit	440.0	425.0
	(¢)	(¢)
Medium-carbon, per lb. Mn	41.50 — 49.00	40.75 — 41.50
Ferromanganese silicon, per lb.	35.0	35.0
Silicomanganese, per lb. of alloy, fob shipping point, freight equalized to nearest main producer, carload lots, lump, bulk		
16-16½% Si, 2%C	24.0	22.5 — 24.0
Manganese metal, electrolytic metal, 99.9%, per lb. Mn, boxed fob shipping point		
Regular	54.0	58.0
6% N	57.0	61.0

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Manganese ore	free	free	free	free
33504-1	Manganese oxide	free	free	free	free
35104-1	Electrolytic manganese metal	free	free	20%	free
37501-1	Ferromanganese, spiegeleisen and other alloys of manganese and iron, not more than 1% Si in the Mn content, per lb.	free	0.5¢	1.25¢	free
37502-1	Silicomanganese, silico spiegel and other alloys of manganese and iron more than 1%, Si on the Mn content per lb.	free	0.75¢	1.75¢	free

United States

Item No.		(¢ per lb on Mn content)
601.27	Manganese ore (duty temporarily suspended to end of June 1979)	0.12
607.35	Ferromanganese, not containing over 1% C	0.3 + 2% ad. val.
607.36	Ferromanganese, containing over 1% but not over 4% C	0.46
607.37	Ferromanganese containing over 4% C	0.3
632.32	Manganese metal, unwrought, waste and scrap (duty temporarily suspended on waste and scrap to end of June 1978)	1.5¢ per lb + 10% ad. val.

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States, Annotated (1976), TC Publication 749.

Mercury

J.G. GEORGE

In 1976 there was no mine production of mercury in Canada. There has been no mine output of mercury since July 1975 when the Pinchi Lake mine of Cominco Ltd., 48 kilometres north of Fort St. James, British Columbia, suspended operations indefinitely. This mine's closure was occasioned by the significant decline in mercury prices that began late in 1974 and continued in 1975. The drop in prices resulted from declining consumption and a world over-supply of the metal. From January 1, 1975 through to the time of closure of the property, the Pinchi Lake mill processed 113 400 tonnes* of cinnabar ore. Beneficiation of the ore involved concentrating it by flotation, then roasting the concentrate to produce mercury vapour which, in turn, was cooled and condensed to produce liquid metallic mercury. In 1975 the roaster produced 12,000 flasks** of refined mercury. The Pinchi Lake mine's ore reserves at the end of 1976 were 1 089 000 tonnes containing 98 000 flasks of mercury. From late 1968, when the mine was reopened, until its closure in 1975, refined mercury output totalled 122 760 flasks, with the greatest annual production being 24 400 flasks in 1970.

Cominco Ltd. also produced high-purity mercury metal with metallic impurities totalling ten parts per billion, or less, at its electronic materials plants at Trail, British Columbia. This specialty metal product was manufactured mainly for special applications in the electronics industry, such as advanced radiation detector materials.

Little exploration and development work was done in 1976 at Canadian mercury mining prospects because the demand and price for the metal continued to remain at relatively low levels.

Canadian imports of mercury metal in 1976, at 62 638 kilograms (1817 flasks), were somewhat lower than the 73 524 kilograms (2133 flasks) imported in 1975. Partial consumption of mercury metal in Canada, as reported by Statistics Canada, was 32 869 kilograms (953 flasks) in 1975; in 1976 it was 26 039*** kilograms (755 flasks).

World review

Estimated world mine production of mercury in 1976 was 245 700 flasks, or slightly less than the 249 226 flasks produced in 1975. The U.S.S.R. retained its status as the world's largest mine producer of mercury. Spain continued to be the world's second largest producer and, together with Italy, accounted for 28 per cent of world output. The seven countries with the largest production, in declining order of output, were U.S.S.R., Spain, the People's Republic of China, Italy, United States, Yugoslavia and Mexico.

According to preliminary statistics for 1976, both Spanish and Italian outputs of mercury were somewhat lower than that of the previous year. On the other hand, United States production was more than triple that of 1975.

The Minas de Almaden Company in Spain, whose Almaden mine is the largest mercury producer in the world, completed construction in 1975 of a new plant at Almaden which uses a new process for treating waste residues from its roaster to yield an additional 5 000 to 10 000 flasks of mercury a year. The current stockpile of residues could reportedly provide an additional 200 000 to 300 000 flasks. Increased production could also come from Algeria where del Monego, an Italian company, was scheduled to bring on stream a new mercury extraction plant near Annaba. The U.S.S.R. plans to build a large mercury mining and metallurgical complex near Magadan on the Chukota Peninsula in eastern Siberia. Construction plans were reportedly authorized after discovery of a deposit of mercury in commercial quantities.

The Bosnian mining enterprise, Srednobosanski Rudnici Uglija, in Yugoslavia, announced in 1975 that it will develop mercury deposits discovered over a five-square-mile area at Drazevici, near Srednje in the

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

**The flask containing 76 net pounds avoirdupois (34.473 kilograms) is used throughout.

***Preliminary Figure.

Ozren mountains. About $1 million has already been spent on prospecting work. The main mineral in the ore is cinnabar and it has been reported that the deposits contain some 300 000 tonnes, sufficient to support a ten-year mining operation. The ore has been estimated to grade between 0.35 and 9.0 per cent mercury, with a mean of about 1.4 per cent.

In September 1976 the Italian state-owned agency, Ente di Gestione per le Aziende Minerarie Metallurgiche (EGAM), which controls the Monte Amiata group of mercury mines in Italy, announced that it was suspending operations for a period of about three years. In the Monte Amiata group there are several mines which operated within a radius of 25 kilometres of a central processing plant. Monte Amiata has, for many years, been the leading mercury producer in Italy and the second largest in the world. Mining operations, which began about 1890, are underground. The plant has a rated annual capacity of 30 000 flasks of mercury, although it has not been producing at this level for the past few years because of the prolonged slump in consumer demand. Because of depressed mercury prices and high worldwide stocks held by both producers and consumers, the Monte Amiata mines have been operating at a loss for several years. Furthermore, the company has accumulated substantial stocks of mercury which are believed to represent several years' output and it will continue to sell from these stocks while its mines are inoperative. During the shutdown period the company will restructure its mining activities. When production resumes, the rated capacity will remain at 30 000 flasks of refined mercury a year but the modernization of the mining operation will improve productivity so that this output can be achieved with a workforce of only 400 instead of 1000 workers.

In the latter part of 1976, and at about the time Monte Amiata suspended operations, Minas de Almaden Company announced that it would withhold supplies of mercury from the market until prices reached acceptable levels. These two actions appeared to result in a firming of the market, and in the last quarter of 1976 New York mercury prices rose from about $115 to $135 flask. European quotations also strengthened significantly.

Because of rising costs of production and the relatively low prices that again obtained in 1976, some of the Mexican mercury mines curtailed production and other small marginal producers ceased operations.

By late 1972 Chinese mercury slowly began to move into western markets, including the United States. Since then it is believed that increasing amounts of Russian, as well as Chinese, mercury have been sold to western countries. Imports of Chinese mercury into the United States increased from 350 flasks in 1975 to 3850 flasks in 1976. Such sales have had a depressing effect on the mercury market and prices.

United States mine output of mercury increased

Table 1. Canadian mercury production, trade and consumption, 1975-76

	1975		1976[p]	
	(kilograms)	($)	(kilograms)	($)
Mine Production	413 676	. .	—	—
Imports (metal)				
United States	48 443	315 000	20 774	102 000
Netherlands	21 454	125 000	21 318	90 000
People's Republic of China	—	—	14 378	38 000
Spain	3 492	35 000	5 307	21 000
Sweden	90	9 000	816	9 000
United Kingdom	45	. . .	45	1 000
Total	73 524	484 000	62 638	261 000
Consumption[1] (metal)				
Heavy chemicals	16 696	. .	12 455	. .
Electrical apparatus	14 413	. .	12 271	. .
Gold Recovery	362	. .	230	. .
Miscellaneous	1 398	. .	1 083	. .
Total	32 869	. .	26 039	. .

Source: Statistics Canada, except for mine production figures which represent output by Cominco Ltd. as reported in its annual reports.
[1] Partial consumption only.
[p] Preliminary; . . Not available; — Nil; . . . Less than $500.

sharply again in 1976 as a result of increased production from the McDermitt mercury property in northern Humboldt County, Nevada. The McDermitt mine began operations in mid-1975 and it will eventually have the capacity to produce refined mercury at a rate of 20 000 flasks a year. The property is being mined by open-pit methods and the ore is processed in a 635-tonne-a-day concentrator, with the flotation concentrate being furnaced in a system containing a multiple-hearth roaster equipped with emission control devices. Ore reserves have been reported to be in excess of 2 700 000 tonnes, grading 0.5 per cent mercury. The primary mineral is cinnabar (HgS), but an unusual feature of the deposit is that about 10 to 30 per cent of the cinnabar in the orebody has been replaced by an uncommon mercury mineral known as corderoite ($Hg_3S_2Cl_2$). The McDermitt mine is about 610 metres north of the Cordero mine which, along with adjacent properties, produced over 115 000 flasks of mercury from 1941 to 1970. Development costs to bring the new mine into production have been reported to be some $9.7 million. Placer Amex Inc., a wholly-owned subsidiary of Placer Development Limited (a Canadian company), has a 51 per cent interest in the McDermitt property, with Minerals Exploration Company of New Jersey holding the remaining 49 per cent. Noranda Mines Limited holds a 31.5 per cent direct interest in Placer Development Limited.

Table 2. Canadian mercury production, trade and consumption, 1967-1976

	Production Metal	Imports, Metal	Exports, Metal	Consumption Metal
	(kilograms)			
1967	—	161 615	. .	111 185
1968	195 117	89 766	. .	148 751
1969	727 380	60 600	. .	140 076
1970	841 141	69 536	. .	154 474
1971	637 750	55 338	. .	87 982
1972	504 581	79 243	. .	51 998
1973	430 912	48 171	. .	32 959
1974	482 622	108 817	. .	37 786
1975	413 676	73 524	. .	32 869[1]
1976[p]	—	62 638	. .	26 039[1]

Sources: Statistics Canada for all figures, except for metal production statistics, obtained directly from Cominco Ltd. and representing output from its Pinchi Lake mine in B.C.
[p] Preliminary; — Nil; . . Not available.
[1] Partial consumption only.

The United States is believed to be the world's largest consumer of mercury but has always produced less than its requirements. Total consumption in 1976 in the United States of primary, redistilled and secondary mercury was estimated at 64 546 flasks, an increase of 27 per cent from the 50 838 flasks consumed in 1975. A large portion of the U.S. requirements was again derived from imports, which totalled 43 964 flasks* in 1976 compared with 44 472 flasks* imported in 1975. The largest suppliers in 1976, in declining order of amount supplied, were Italy, Algeria, Yugoslavia, Spain, the People's Republic of China and Canada. Together, these six countries accounted for 95 per cent of total imports by the United States. Imports from Canada alone declined from 12 891 flasks in 1975 to 2854 flasks in 1976. Mexico, once a major supplier, exported only 1717 flasks of mercury to the United States in 1976.

The largest increases in United States mercury consumption in 1976 were noted in the metal's uses in electrical apparatus and mildew-proofing paints. The only significant downturn in demand occurred in dental preparations.

World consumption of mercury in 1976 is believed to have been about 245 000 flasks, or about 20 000

*Reported in United States, Department of the Interior, Bureau of Mines, Mineral Industry Surveys "Mercury in the Fourth Quarter 1976".

Table 3. World production of mercury, 1972, 1975 and 1976

	1972	1975[p]	1976[e]
	(flasks)		
U.S.S.R.[e]	50,000	55,000	55,000
Spain	53,994	47,051	45,000
People's Republic of China[e]	26,000	26,000	26,000
Italy	41,801	30,400	24,000
United States	7,349	7,366	23,400
Yugoslavia	16,419	16,941	16,000
Mexico	22,510	14,184	14,000
Algeria	13,361	13,300	13,000
Turkey	7,963	8,800	. .
West Germany	2,900	7,000	. .
Czechoslovakia	6,614	6,000	. .
Peru	4,550	3,500	. .
Philippines	3,341	232	. .
Japan	5,019	—	—
Ireland	1,250	800	. .
Canada[1]	14,637	12,000	—
Other countries	1,260	652	29,300
Total	278,968	249,226	245,700

Sources: Preprints from the 1974 and 1975 U.S. Bureau of Mines *Minerals Yearbook*, for 1972 and 1975 statistics, respectively, U.S. Bureau of Mines *Commodity Data Summaries 1977*, for most of the 1976 statistics.
[1] Output of Cominco Ltd. as reported by that company.
[p] Preliminary; [e] Estimated; . . Data not available but estimate included in figure for "other countries".

flasks greater than in 1975. The increase resulted mainly from an improvement in the economies of some of the consuming countries. In some large industrial nations, including the United States, growth in the use of mercury in some of its applications continued to be impeded by unfavourable publicity from the advocates of less pollution of the environment. One of the metal's major uses, as a cathode in the electrolytic preparation of chlorine and caustic soda, continued to be a principal target of the ecologists because of the danger of pollution from the effluents. The danger of mercury poisoning has also continued to adversely affect other outlets for the metal, such as the agricultural, pulp and paper, and paint industries.

For the past several years delegates from most of the major producing countries have held meetings in different countries at least once a year. The meetings have been producer-oriented and one of the main items on each agenda has always been an attempt to bring about more stability to the mercury market, mainly by agreeing on concerted measures to control supplies and regulate prices. In December 1976 this group of world producers, known as the International Association of Mercury Producers (ASSIMER), met again in Geneva, Switzerland, reportedly to discuss mainly the mercury price and market situation. The member countries of the organization, established in 1975, are Spain, Italy, Turkey, Yugoslavia, Algeria and Peru, which together account for about 90 per cent of the non-communist countries' exports of mercury. Most of the member governments control their countries' mercury production; only in Turkey is a form of private ownership allowed. ASSIMER's headquarters are in Geneva. Among the objectives of the association are stabilization of prices by curtailing production or withholding supplies from the market, the development of new uses for mercury and an improvement in its environmental image, and the promotion of the interests of the members of the association.

Table 4. United States mercury consumption, by uses, primary and secondary in origin.

	1972	1975	1976[p]
		(flasks)	
Agriculture[1]	1,836	600	707
Amalgamation	—	7	—
Catalysts	800	838	473
Dental preparations	2,983	2,340	1,686
Electrical apparatus	15,553	16,971	26,423
Electrolytic preparation of chlorine and caustic soda	11,519	15,222	15,433
General laboratory use	594	335	529
Industrial and control instruments	6,541	4,598	4,572
Paint:			
Antifouling	32	—	—
Mildew-proofing	8,190	6,928	7,846
Paper and pulp manufacture	1	—	—
Pharmaceuticals	578	445	361
Other[2]	4,258	1,750	3,026
Total known uses	52,885	50,034	64,546[3]
Unknown uses	22	804	. .
Grand Total	52,907	50,838	64,546

Sources: Preprint from the 1975 U.S. Bureau of Mines *Minerals Yearbook*, for 1972 and 1975 statistics. U.S. Bureau of Mines, *Mineral Industry Surveys*, "Mercury in the Fourth Quarter 1976", for 1976 statistics.
[1]Includes fungicides and bactericides for industrial purposes. [2]Includes mercury used for installation and expansion of chlorine and caustic soda plants. [3]The individual items do not add to the total which has been increased to cover approximate total consumption.
[p]Preliminary; — Nil; . . Not available.

At the end of 1976 United States government national (strategic) and supplemental stockpiles contained a total of 191 407 flasks of mercury, a reduction of 8 655 flasks from the total on hand at the end of 1975. Late in 1976 the stockpile objective was raised from 42 700 to 54 004 flasks, leaving a surplus of 137 403 flasks, none of which may be released, however, without U.S. Congressional authorization. Such stocks are exclusive of excess mercury held by the United States Atomic Energy Commission (USAEC). In June 1969 these surplus USAEC stocks, which do not require Congressional authorization prior to being sold, were declared to be 15 000 flasks. Between then and the end of 1975, a total of 13 225 flasks were sold, or released to other government agencies, leaving a surplus of 1775 flasks of USAEC mercury available for disposal at December 31, 1975. General Services Administration (GSA) continued its offerings of such stocks in 1976 at the rate of 500 flasks (maximum) a month, with metal so released being restricted to domestic consumption until August 1976 when export sales were permitted. GSA released only 520 flasks in 1976, leaving a surplus of 1255 flasks of USAEC mercury at December 31, 1976.

World inventories of mercury held by producers continued to rise and at the end of 1976 were estimated at 260 000 flasks. The combined total held by Spain and Italy alone was believed to be in excess of 150 000 flasks. In the United States stocks of mercury held by producers increased from 4858 flasks at the end of 1975 to 9494 flasks at the end of 1976.

In March 1974 the United States Environmental Protection Agency (EPA) promulgated its final effluent limitation guidelines for existing and new sources in the inorganic chemicals manufacturing category. The daily effluent limitation is 0.00028 pound of mercury per 1000 pounds of product for mercury-cell plants in existence since March 1974. The limitation is 0.00014 pound of mercury per 1000 pounds of product for new producing plants. One of the stated goals of the Federal Water Pollution Control Act of 1972 is the elimination of all pollutant discharges by 1985.

On April 6, 1973 EPA published the final air emission standard for mercury at 5.1 pounds a day, per plant, released to the atmosphere. In 1974, EPA proposed an amendment to the emission standard for hazardous air pollutants in which mercury emissions from the incineration and drying of wastewater treatment plant sludges would be limited to a maximum of 3200 grams (7.05 pounds) per day. Further, the National Institute for Occupational Safety and Health submitted criteria for a recommended standard on the occupational exposure to inorganic mercury. On March 14, 1975 EPA proposed National Interim Primary Drinking Water Regulations and held hearings thereafter on the proposed regulations. In addition, comments and information were received from representatives of State agencies, public interest groups and others. The regulations proposed maximum contaminant levels in public drinking water and set the mercury level at 0.002 milligram per litre.

In 1975, EPA concluded its hearings on the cancellation of biocidal uses of mercury, including mildewcides in paint. Early in 1976 EPA ordered an immediate halt to the use of mercury compounds in pesticides. Later in the same year EPA rescinded its ban on the use of mercury compounds in some agricultural products and postponed the ban for other uses. The use of mercury in winter disease control products for golf courses was reinstated permanently. For other agricultural uses — summer disease control and seed protection — the manufacturers of the control products can continue to use mercury until August 1978. EPA also reinstated the use of mercury compounds in latex (water-based) paints but continued the ban on their use in nonwater-based paints. EPA also requested a review of the uses of mercury in other pesticides.

In Canada, legislation, known as the "Chlor-Alkali Mercury Regulations" (P.C. 1972-576), was passed by the federal government March 28, 1972 and became effective 60 days after that date. This legislation restricted the quantity of mercury that may be discharged in the effluent from any chlor-alkali plant in Canada using the mercury-cell process. It stipulates that mercury in the liquid effluent, from any such chlor-alkali plant, deposited in any one day in waters frequented by fish shall not exceed 0.005 pound per ton of chlorine produced by the plant in that day.

Also in Canada, the Food and Drugs Act, a federal statute (Chapter F-27 R.S.C., 1970, as amended) is designed, among other things, to protect Canadians against health hazards related to foods. The Act is administered by the Health Protection Branch of the Department of National Health and Welfare. Section 4 (a) of the Act provides legal authority for the Branch to determine those levels in foods of substances such as mercury, which are considered to represent a hazard to human health, and to prohibit the sale of foods containing unsafe levels of the substances in question. After a study of the available data on the toxic effects to humans of mercury-contaminated fish, the consumption of fish by Canadians, and action taken by other countries on this matter, the Health Protection Branch decided in 1969 that, as a temporary measure, it would take no exception to the sale of fish containing not more than 0.5 part per million (ppm) of mercury determined on a wet basis. In effect, this 0.5 ppm mercury level represents an administrative guideline applicable to fish only, and legally binding only at the point of sale. Apparently this same 0.5 ppm mercury level in fish was subsequently adopted by the United States government authorities.

Outlook

Mercury prices remained depressed throughout 1976 because of poor demand resulting from sluggish world economic conditions, excessive stocks and substitution due to the adverse publicity from ecological sources. In Italy the Monte Amiata group of mercury mines suspended operations because of depressed world prices, and in Canada the Pinchi Lake mine of Cominco Ltd. in British Columbia remained shut down for the same reason.

In 1977, mercury prices could strengthen somewhat, partly because of higher costs of production, but mainly because of better economic conditions in the United States and the anticipated improvement in the economies of Europe and Japan. A bullish factor was the announcement in March 1977 that Yugoslavia's largest mercury producer, the state-owned Idrija mine, reportedly decided to suspend operations. This mine has an annual capacity of 15 000 flasks of mercury. Excessive worldwide stocks will, however, continue to keep a damper on any price increases. In the next few years mercury prices might again show distortions similar to those of the past because of erratic demand. Much will depend on the outcome of the efforts of the major producers to control production and offerings to the market and, hence, prices. There is also the risk that rising prices, if sustained for any period, could lead to the reopening of mercury mines that cannot be operated economically under present conditions.

In addition to the high worldwide stocks held by producers and consumers, there is also overhanging the mercury market the substantial quantity of more than 190 000 flasks in the United States government's strategic stockpiles. Another bearish factor is the increasing quantities of Russian and Chinese mercury being disposed of in Western Europe and the United States. In 1976 the United States imported 3853 flasks of mercury from the People's Republic of China compared with only 350 flasks in 1975.

Because of environmental factors, another negative influence on the mercury market in the medium-term (up to 1980), will be the trend to greater use of the diaphragm cell (which requires no mercury) in the electrolysis of brine to produce chlorine and caustic soda. At present, more than two thirds of the chlorine produced in the United States is made in diaphragm cells, whereas in western Europe over 80 per cent is made in mercury cells. The mercury cell process for the electrolytic preparation of chlorine and caustic soda is currently one of the two major uses for mercury (the other being for electrical apparatus). While the short chlorine supply situation envisaged by the industry over the next few years will continue to spur expansion of chlor-alkali plants in the United States, none of the plants now under construction or on the drawing board will use the mercury cell. Also, some of the plants in the United States, Canada and Japan that were using the mercury cell have either dismantled their facilities or converted to the diaphragm cell. It is still the policy of the Japanese government to have all chlor-alkali plants in Japan using the mercury cell change over to the diaphragm cell process by March 1978. The excess secondary mercury released for recycling by these plants which are either being dismantled or making the changeover has a further depressing effect on the market.

Although environmental problems will continue to check the growth in the overall use of mercury until at least 1980, there is one bright spot in the outlook for the metal. Its consumption in the electrical apparatus industry is growing significantly and is likely to continue to do so for an indefinite period. In the United States alone 26 423 flasks of mercury were used for electrical apparatus in 1976 compared with 16 971 flasks in 1975. Also, an increase in demand could eventually result from the concerted efforts being made by the new mercury producers' association to find new uses and markets for the metal and its compounds. The development of improved antipollution technology could help the metal to achieve a better image.

Uses

One of the oldest, but now relatively unimportant, applications of mercury is for recovering gold and silver from their ores by amalgamation. The two major uses in recent years have been for electrical apparatus and for the electrolytic production of chlorine and caustic soda. Together, these two uses accounted for over 65 per cent of mercury consumed in the United States in 1976. Electrical uses include mercury lamps, batteries, rectifier bulbs, oscillators, and various kinds of switches including "silent" switches for use in housing. Because mercury lamps are more adaptable to higher voltage supply lines than the lines used with incandescent lamps, they are used as fluorescent lamps and for industrial and street lighting purposes. The mercury battery invented in 1944 is basically a dry-cell type battery. It has a relatively long shelf life and can withstand high temperature and high humidity. It is used in Geiger-Muller counters, portable radios and two-way communications equipment, digital computers, electronic measuring devices, hearing aids, guided missiles, and spacecraft.

Other applications are in mildew-proofing paints, industrial and control instruments, pharmaceuticals, insecticides, fungicides, bactericides and dental preparations, although in some countries some of these uses have already been restricted or banned by governmental regulations. Several mercury compounds, expecially chloride, oxide and sulphate, are good catalysts for many chemical reactions, including those involved in the making of plastics. Because of its capacity to absorb neutrons, the metal has been used as a shield against atomic radiation. One of the more recently developed applications for mercury is in frozen mercury patterns for manufacturing precision or investment castings. Here, mercury is superior to wax, wood or plastic materials because of its smooth surface and uniform expansion upon heating. New technologies could open up new areas of use in the nuclear, metal-chloride vapour, plastic, chemical, amalgam and ion exchange fields. Substitutes for mercury include nickel-cadmium or other battery systems for electrical apparatus, diaphragm cells for mercury cells in the chlor-alkali industry, organotin compounds in paints and solid-state devices for industrial and control instruments.

Prices

Mercury prices fluctuated in a rather wide range from the beginning of 1976 until early September, when

Table 5. Average monthly prices of mercury in 1976 at New York and cif main European port

		cif main European port[2]	
	New York[1]	Low	High
		($U.S./flask)	
January	117.000	79.556	83.444
February	124.722	91.875	97.125
March	128.217	96.444	101.667
April	127.091	98.000	103.250
May	113.500	83.500	89.375
June	109.636	81.333	86.333
July	109.048	80.000	85.000
August	108.182	80.750	85.750
September	122.429	85.250	90.250
October	132.250	97.555	102.888
November	131.421	98.222	105.333
December	132.130	104.875	111.875

Sources: *Metals Week* for New York prices; *Metal Bulletin* (London) for cif main European port prices.
[1]Consensus of fixed-price prompt sales of 20 or more flasks of prime virgin metal in the United States. Price includes delivery, United States import duty, plus any applicable surcharges. [2]Prices are cif main European port, min. 99.99 per cent.

they turned sharply upward and reached a peak of $137 a flask (New York price) about mid-October. In the last quarter of 1976 New York prices remained at higher levels in the range of $130 to $135 a flask. The price of mercury per flask, in New York, as quoted in *Metals Week*, ranged between a high of $138 a flask in April and a low of $106 a flask in May. Average for the year was $121.30 a flask, compared with an average of $158.12 for 1975. In May 1976, the cif main European port price, as quoted in *Metal Bulletin* (London), ranged between a high of $125 (U.S.) a flask in December and a low of $70 (U.S.) in May.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92805-2	Mercury metal	free	free	free	free
92828-4	Mercury oxide for manufacture of dry-cell batteries (expires February 28, 1981)	free	free	25%	free

United States

Item No.		Non-communist countries	Communist countries except Yugoslavia
601-30	Mercury ore	free	free
632-34*	Mercury metal, unwrought and waste and scrap	12.5 cents per pound	25 cents per pound

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), TC Publication 749.
*The suspension of duty on waste and scrap was extended until June 30, 1978.

Molybdenum

R.F. JOHNSON

Canadian mine shipments of molybdenum rose some 10.7 per cent in 1976; the value of shipments, however, increased about 30 per cent from that in 1975. The tight market and the recent increases in the price of molybdenum products sparked renewed interest in several molybdenum deposits in Canada. One former byproduct producer, Gibraltar Mines Ltd., plans to again begin recovering molybdenum in 1977. Canadian consumption fell 10 per cent in 1976 because of reduced demand in the iron and steel industry.

World consumption in 1976 exceeded production for the fourth consecutive year. Consumer stocks continued to fall, and approached minimum levels by year-end. One new mine, the Henderson mine of AMAX Inc. (AMAX) in the United States, began production during the year. There were three price increases in 1976.

Molybdenum is expected to remain in short supply through the early 1980s. Production from new mines in the next five years is not expected to be sufficient to compensate for the increased demand, the loss of production resulting from mine closures and the present imbalance in supply and demand. Prices are expected to increase in real terms, with additional increases particularly likely in 1977-78 and 1980-81.

Canada, production, trade and consumption

Canadian shipments of molybdenum in concentrate, molybdic oxide and ferromolybdenum were some 14 416 tonnes* in 1976, valued at $91.9 million; up from 13 027 tonnes in 1975, valued at $71.2 million. Molybdenum was produced at six mines in Canada in 1976 (Table 3). Mine production dropped some 200 tonnes during the year; however, mine shipments increased as there was a 700-tonne drawdown in producer inventories. There are two plants in Canada capable of converting molybdenite (MoS_2) concentrates to molybdic oxide. One is part of the Endako operations in British Columbia and treats only concentrate produced at the Endako mine; the other, which is operated by Fundy Chemical International Ltd., is located at Duparquet, Quebec and primarily treats concentrate on a toll basis. One company, Masterloy Products Limited, near Ottawa, produces ferromolybdenum from imported molybdic oxide for Noranda Mines Limited.

One former producer, Gibraltar Mines Ltd., will again be recovering molybdenum from its copper-mining operation in British Columbia in 1977. Gibraltar, a subsidiary of Placer Development Limited, stopped recovering molybdenum in 1975 when the recovery was deemed uneconomic. The company is expected to produce at an annual rate of about 250 tonnes of molybdenum in concentrate. No other new sources of production are expected before the end of this decade.

Placer Development Limited handles sales to Pacific Rim countries for its subsidiary, Endako. Noranda Sales Corporation Ltd. (Noranda) markets the concentrate from Brenda Mines Ltd. (Brenda) Brynnor Mines Limited (Brynnor) and Gaspé Copper Mines Limited (Gaspé), as well as handling domestic and European sales for Endako. Noranda holds 31.5 per cent of the outstanding shares of Placer while Brenda, Brynnor and Gaspé are all wholly or partly-owned subsidiaries of Noranda. The output from Lornex Mining Corporation Ltd., a subsidiary of Rio Algom Limited, and Utah Mines Ltd. are sold to a trading company, Philipp Brothers, Division of Engelhard Minerals & Chemicals Corporation, under long-term contracts.

Noranda is currently considering the possibility of increasing production at the Boss Mountain deposit of its wholly-owned subsidiary, Brynnor Mines Limited. Brynnor operated an underground mine on the property from 1965 to 1971, when it was closed due to poor market conditions, and again from 1974 to the present. The remaining underground reserves are only sufficient for another three years of operations. During 1975 and 1976, Noranda drilled over 70 holes on a much-larger, but lower-grade portion of the orebody. It is expected that an open-pit mine will be developed on this portion in the early 1980s. Envisaged production is

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

in the order of 4 500 tonnes of molybdenum in concentrate a year. Another property that will probably be brought into production in the early 1980s is that of a now-defunct producer, British Columbia Molybdenum Limited. The property, which is currently held by AMAX Inc., is believed to contain more than 100 million tonnes of ore averaging from 0.15 to 0.20 per cent molybdenite. Prior to its closure in 1972, British Columbia Molybdenum produced at a rate of 2 500 tonnes of molybdenum a year. When the mine is again brought into production, it is estimated that this capacity will be increased to an annual rate of 4 500 tonnes.

The strong market for molybdenum rekindled interest in several molybdenum properties in British Columbia during 1976. Among these, was the Carmi deposit, which was optioned by Craigmont Mines Limited from the present holder, Vestor Explorations Ltd. Craigmont undertook a drilling program on the deposit; however, no results have been announced. Prior to this current program, some 36 million tonnes averaging 0.15 per cent molybdenite had been identified through earlier drilling.

Table 1. Canada, molybdenum production, trade and consumption, 1975-76

	1975		1976[p]	
	(kilograms)	($)	(kilograms)	($)
Production (shipments)[1]				
British Columbia	13 026 696	71 201 391	13 955 000	88 927 000
Quebec	. .	. .	461 000	2 946 000
Total	13 026 696	71 201 391	14 416 000	91 873 000
Exports				
Molybdenum in ores and concentrates and scrap[2]				
Japan	3 924 164	19 115 000	4 865 504	31 035 000
Belgium and Luxembourg	5 432 132	24 785 000	4 028 218	24 255 000
United Kingdom	2 199 469	9 806 000	2 274 856	13 493 000
Netherlands	826 128	4 905 000	961 979	5 671 000
United States	1 193 628	4 019 000	1 104 361	5 226 000
West Germany	1 188 367	6 406 000	519 318	2 731 000
France	273 335	1 047 000	422 612	2 679 000
India	51 165	339 000	133 628	742 000
Australia	63 367	453 000	74 616	375 000
Other countries	528 344	2 401 000	165 698	958 000
Total	15 680 099	73 276 000	14 550 790	87 165 000
Imports				
Molybdic oxide (gross weight)	56 382	257 000	111 631	566 000
Molybdenum in ores and concentrates[3] (Mo content)	525 033	2 717 085	169 077	855 648
Ferromolybdenum[3] (gross weight)	269 281	929 017	128 845	673 603
Total	na	3 903 102	na	2 095 251
Consumption (Mo content)				
Ferrous and nonferrous alloys	1 372 716	. .	. .	. .
Electrical and electronics	7 593	. .	. .	. .
Other uses[4]	56 574	. .	. .	. .
Total	1 436 883	. .	1 250[e]	. .

Source: Statistics Canada, except where noted.
[1]Producers' shipments (Mo content) of molybdenum concentrates, molybdic oxide and ferromolybdenum. [2]Includes molybdenite, molybdic oxide in ores and concentrates. [3]United States exports of molybdenum to Canada, reported by the U.S. Bureau of Commerce, Exports of Domestic and Foreign Merchandise (Report 410), value in U.S. currency. These imports are not available separately in official Canadian trade statistics. [4]Chiefly pigment uses.
[p]Preliminary; . . . Not available; [e]Estimated; na Not applicable.

Fundy Chemical, and Derek Raphael and Company, entered into a joint venture agreement to process molybdenite concentrates in 1976 at Duparquet, Quebec. The joint venture, which will combine some of Fundy's roasting and ferromolybdenum production capacity with Raphael's marketing structure, will lease some of Fundy's production capacity at Duparquet. Raphael will purchase concentrates for conversion at Duparquet and market the products internationally. No announcements on possible sources of concentrate or on the volume involved have been made. To date, Fundy has been converting on a toll basis only.

Canadian exports of molybdenum in all forms dropped from 15 680 tonnes in 1975 to 14 551 tonnes in 1976. The lower level of exports in 1976 resulted from an increase in domestic shipments and a lower level of shipments from stocks. Canadian exports to Japan are primarily in the form of oxide, with Endako being the major supplier. Conversely, most Canadian exports to Europe are in the form of concentrate. The concentrate is usually roasted in Europe on a toll basis for Canadian producers and delivered as oxide. Some oxide is also exported to Europe direct from Canada. The material going to the United States is principally concentrate from Lornex and Utah that Philipp Brothers has converted in that country.

Canadian imports of molybdenum in all forms dropped dramatically in 1976. AMAX Inc., which had supplied about 40 per cent of Canadian demand, stopped shipping to the Canadian market during the year. The reason given for this withdrawal was that the continuing high level of demand in the United States and by AMAX's major consumers in Japan and Europe forced the company to withdraw from all its smaller and more marginal markets, including Canada. This shortfall on domestic supplies was made up by increased domestic shipments from Endako. Fundy Chemical was especially hard-hit by this withdrawal. Since Canada has a 15 per cent tariff on molybdic oxide, but no tariff on concentrate, foreign suppliers used to ship concentrate into Canada and have it toll-converted by Fundy. Fundy's plant has been idle throughout most of 1976.

Canadian consumption dropped 10 per cent in 1976 to some 1 250 tonnes of molybdenum contained in all forms. Well over 90 per cent of the molybdenum consumed in Canada is used in the iron and steel industry and demand in this area dropped by 200 tonnes in 1976. Consumption in other areas of the economy actually increased, but this increase was far from sufficient to balance the decrease in the steel industry. The major products consumed in Canada are: molybdic oxide for use in the iron and steel industry and, in its purified form, for the manufacture of catalysts and other chemicals; ferromolybdenum for use in the iron and steel industry; molybdenum metal for use in the iron and steel industry and for the production of non-ferrous alloys; molybdenum wire for use in the electrical and electronics industry; and molybdenum disulphide for use in the manufacture of molybdenum-based lubricants and in wheel linings for railroad cars. The major consumers by industry group in Canada are:

Table 2. Canada, molybdenum production, trade and consumption, 1965, 1970, 1974-76

	Production[1]	Exports[2]	Imports		Consumption[5]
			Molybdic oxide[3]	Ferro-molybdenum[4]	
	(kilograms)				
1965	4 335 069	. .	344 503	180 738	772 281
1970	15 318 593	13 763 807	33 520	29 619	1 036 940
1974	13 941 775	12 690 471	85 910	267 044	1 673 146
1975	13 026 696	15 680 099	56 382	269 281	1 436 883
1976[p]	14 416 000	14 550 790	111 631	128 845	1 250 000[e]

Source: Statistics Canada.
[1]Producers' shipments (Mo content) molybdenum concentrates, oxide and ferromolybdenum. [2]Mo content, ores and concentrates. [3]Gross weight. [4]U.S. exports to Canada, reported in United States Exports of Domestic and Foreign Merchandise, gross weight. [5]Mo content of molybdenum products reported by consumers.
[p]Preliminary; [e]Estimated; . . Not available.

Iron and steel

Abex Industries Ltd.
The Algoma Steel Corporation, Limited
Atlas Steels Company Limited
Canron Limited
Colt Industries (Canada) Ltd.
Dominion Foundries and Steel, Limited
Esco Limited
Fahralloy Canada Limited
Ford Motor Company of Canada, Limited

Iron and steel

Indiana Steel Products Limited
The Steel Company of Canada, Limited
Welmet Industries Limited

Electrical and electronic products

Canadian General Electric Company Limited
Westinghouse Canada Limited
GTE Sylvania Canada Limited

Non-ferrous alloys

Deloro Stellite Division of Canadian Oxygen Limited

Chemicals, Paints and Lubricants

Alchem Limited
Acheson Colloids (Canada) Limited
Cyanamid of Canada Limited
Dominion Colour Corporation Limited
Forsythe Lubrication Associates Limited
Hercules (Canada) Limited
Imperial Oil Limited
Kerns-Keystone Division of Pennwalt of Canada Limited
Molyslip Industrial Lubricants Inc.

Wheel linings

Canadian National Railway Company
Canadian Pacific Railway Company

Consumer stocks in Canada fell to about 175 tonnes in 1976, down from 280 tonnes in 1975.

If approval is given to begin construction of a natural gas pipeline in northern Canada, this could lead to a substantial increase in molybdenum consumption in Canada. It is highly probable that the pipe for any of the pipeline routes chosen will use molybdenum-bearing steels. Depending on the final specifications for the pipe, it is estimated that from 5 000 to 8 000 tonnes of molybdenum would be required for the Canadian section of a pipeline. This demand would, however, only be temporary and would be expected to last for a period of three to four years.

Production and marketing

Molybdenum reserves and resources are not widely distributed. They tend to be concentrated in a belt that starts on the west coast of South America, extends through the western part of North America, and slices through Asia ending in the area of the Caspian Sea. Estimated reserves and resources of molybdenum are:

	Reserves	Resources
	(000 000 tonnes Mo)	
United States	3.0	13.0
Canada	0.9	3.7
Chile	0.8	1.7
U.S.S.R.	0.9	1.4
Other	0.4	2.8
Total	6.0	22.6

Source: Molybdenum Chapter, *Mineral Facts and Problems.*

Most of these reserves are found in porphyry deposits where molybdenum occurs as the principal mineral, or in association with copper.

This concentration of reserves in certain countries has led to an equivalent concentration in production. In 1976, production was roughly distributed as follows:

	Per cent of World Production
United States	57
Canada	17
Chile	13
U.S.S.R.	11
Other	2
Total	100

Source: Department of Energy, Mines and Resources, Ottawa.

Molybdenum was first produced on a large scale in the United States and it has been largely through the efforts of a few companies, particularly AMAX Inc., that molybdenum has become one of the most commonly used alloying agents. During the market development stage, few companies showed interest in molybdenum and it has only been in recent years that molybdenum has become of widespread interest in the mining industry. As a consequence, molybdenum production has remained relatively concentrated, corporately. In 1976, corporate production of molybdenum in free market economy countries was roughly distributed as follows:

Company	Country	Per cent of Production
AMAX Inc.	U.S.	38
Duval Sierrita Corporation	U.S.	12
Corporation del Cobre de Chile	Chile	10
Placer Development	Canada	10
Noranda	Canada	7
Molycorp Inc.	U.S.	6
Kennecott Copper Corporation	U.S.	4
Others		13
Total		100

Source: Department of Energy, Mines and Resources, Ottawa.

The dominance of these producers is expected to continue as they hold most of the commercially attractive properties. AMAX is expected to increase its share of production following the opening of a new mine in the United States in 1976.

Molybdenum is mined as molybdenum disulphide (MoS_2). The sulphide has few uses and most is converted to other forms prior to use. This conversion is done in a roaster where the MoS_2 in the concentrate is transformed to molybdic oxide (MoO_3). Virtually all of the molybdenum used must first be converted to oxide. Ferromolybdenum, molybdenum metal and molybdenum chemicals are all produced from the oxide, which in itself is widely used. Most of the world's molybdenum-roasting capacity is controlled by mine producers.

The major consuming regions are the United States, Japan and Western Europe. The approximate shares of these markets held by producers are:

	Western* Europe	United States	Japan
		(per cent)	
United States	55	90	50
Canada	25		45
Chile	20	10	—
Others	—		5
Total	100	100	100

*includes exports to eastern Europe.
Source: Department of Energy, Mines and Resources, Ottawa.

Most of the trade with Japan is in the form of molybdic oxide while concentrate is the more important form in Europe.

Molybdenum in 1976

In 1976 molybdenum consumption exceeded production for the fourth consecutive year (Table 4). Production increased some 2.5 per cent in 1976 to 77 000 tonnes of contained molybdenum, with small increases in production being recorded in the United States and Chile. Consumption increased some 7 per cent in 1976 to 83 000 tonnes with gains being recorded in all principal markets. Because of the continued short supply situation, there was a further reduction in the level of producer and consumer stocks. Consumer stocks are less than the equivalent of two months consumption in Canada, about two months in the United States and reportedly three months in Japan. This reduction of consumer stocks to near-minimum levels will place greater pressure on the market in 1977.

A contributing factor to the continuing supply shortage has been the relatively poor market for copper. As indicated in Table 5, some 28 000 tonnes of molybdenum are recovered as a byproduct, almost all of it exclusively as a byproduct of copper. Although world byproduct production has held reasonably constant, there has been a 40 per cent decline in byproduct production in the United States. While the loss in production involved is not tremendously large, it would have been sufficient to avert the shortages of the last two years.

Table 3. Canada, production, stocks and reserves at Canadian mines, 1975-76

Company	Type of Producer	Production 1975	Production 1976	Year-End Stocks 1975	Year-End Stocks 1976	Reserves (Dec., 1976) Tonnage	Reserves (Dec., 1976) Grade
				(000 tonnes contained Mo)			($\%MoS_2$)
Endako Mines Division Canex Placer Limited	Primary	6.8	6.8	2.1	2.1	210 000	0.141
Brynnor Mines Limited	Primary	1.1	1.0	—^{e}	—^{e}	800	0.400
Utah Mines Ltd.	Byproduct	0.7	0.6	0.6^e	0.4^e	250 000	0.029
Lornex Mining Corporation Ltd.	Byproduct	1.4	1.7	0.3	0.3	500 000	0.025
Brenda Mines Ltd.	Coproduct	3.9	3.6	1.9^e	1.4^e	117 000	0.071
Gibraltar Mines[1] Ltd.	Byproduct	—	—	—	—	312 000	0.019
Gaspé Copper Mines, Limited	Byproduct	0.1	0.1	—	—	251 000	0.008
Total		14.0	13.8	4.9	4.2	1 640 800	Average grade: 0.04

Sources: Company annual reports; Canadian Mines Handbook, 1977-78; Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Last produced in 1975.
— Less than 50 tonnes; ^{e}Estimated.

Unlike most mineral commodities, the demand for molybdenum has remained strong despite the general downturn in the world economy. A major factor in this demand has been the increasing amounts of molybdenum being used in steel for the energy and energy-related industries. In 1976 it is estimated that over one million tonnes of molybdenum-bearing steel was produced for use in large-diameter oil and gas transmission pipelines. These steels generally contain from 0.3 to 0.5 per cent molybdenum. Pipelines constructed, or being constructed, in the U.S.S.R., the United States, Canada and in the area of the North Sea have been the major users of this steel. With other pipeline projects scheduled for construction, such as the Alcan Pipeline, the demand in the energy sector is expected to continue its strong growth. Another new and important usage has been the use of molybdenum-bearing steels as casing for deep, sour natural gas wells. These natural gas fields were not generally regarded as commercial sources of natural gas until the dramatic increase in energy prices that occurred in 1974. These molybdenum steels are used because they provide good resistance to corrosion by hydrogen sulphide at the elevated temperatures usually encountered in these fields.

International developments

United States. The Henderson mine of AMAX in Colorado produced its first concentrate in 1976. The mine, which was developed at a cost of over $500 million, has a capacity of some 23 000 tonnes of molybdenum in concentrate a year. This capacity, however, will not be reached until the early 1980s as the caving system used in the mine to produce the ore will not be fully developed until that time. In 1976 the Henderson mine produced some 1 500 tonnes of molybdenum, principally from the milling of ore removed during the development stage. Production is expected to rise to 10 000 tonnes in 1977 and to 16 000 tonnes in 1978. Ore reserves on the property are estimated to be some 300 million tonnes averaging 0.49 per cent MoS_2, with a cut-off grade of 0.20 per cent MoS_2. AMAX will also bring a new roaster into production at Fort Madison, Iowa in 1977.

United States Borax & Chemical Corporation, a subsidiary of Rio Tinto Zinc Corporation Limited, announced that it had identified a large area of molybdenum mineralization in southeastern Alaska in 1976. Preliminary drilling has indicated 100 million tonnes of

Table 4. World[1] supply and demand balance for molybdenum, 1973-1976

	1973	1974	1975	1976
	(000 tonnes contained Mo)			
Production				
U.S.	53	51	49	50
Canada	14	13	15	15
Chile	6	8	10	11[e]
Other free-market countries	1	1	1	1
Total	74	73	75	77
Consumption				
U.S.	32	34	26	28
Western[2] Europe	35[2]	42[2]	30	31
Eastern[2] Europe	na	na	7[3]	7[3]
Japan	10	12	10	11
Other	5	6	5	6
Total	82	94	78	83
Indicated change in world stocks	-8	-21	-3	-6

Source: AMAX Inc., 1976 Annual Report.
[1]Includes exports to eastern Europe and the People's Republic of China only. [2]Includes exports to eastern Europe for 1973 and 1974. [3]Exports to eastern Europe only.
[e] Estimated by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
na Not applicable.

ore averaging between 0.25 and 0.30 per cent MoS_2. U.S. Borax will do preliminary feasibility and environmental impact studies on the deposit in 1977 in addition to undertaking further drilling.

The Questa Molybdenum Company, a joint venture of Molycorp Inc., and Kennecott Copper Corporation, continued drilling on Molycorp's Questa, New Mexico property. To date, the drilling has indicated about 75 million tonnes averaging 0.37 per cent MoS_2. Further drilling will be done in 1977 and a production decision is expected in 1978. Molycorp currently operates an open pit in the Questa area but it is probable that this mine will cease production in the early 1980s because of its high stripping ratios. It is likely that a new underground mine to replace the open pit will be developed on the deposit now being drilled.

Table 5. Estimated production of byproduct and coproduct molybdenum

	1973	1974	1975	1976
	(000 tonnes contained Mo)			
United States	15	13	9	9
Canada	6	6	6	7
Chile	6	8	10	11
Other free-market countries	1	1	1	1
Total	28	28	26	28

Source: Department of Energy, Mines and Resources, Ottawa.

Byproduct molybdenum production in the United States is expected to decline further in 1977. Increasing inventories of copper will probably result in further curtailments at some byproduct producers or, possibly, in temporary closures. There is also the possibility that production may be disrupted by a strike, as the contract covering workers in most copper mines expires in the summer of 1977.

The General Services Administration released the last of the molybdenum held in the strategic stockpile during 1976. Releases in 1976 were some 59 tonnes of molybdenum in concentrate. The new stockpile objectives set by the Federal Preparedness Agency did not contain any provisions for molybdenum.

Chile. Molybdenum production in Chile has risen significantly in recent years, from less than 5 000 tonnes in 1973 to almost 11 000 tonnes in 1976. This is due to major efforts by Chilean copper producers to recover molybdenum that had previously gone to tailings. Corporacion Nacional del Cobre de Chile (Codelco) began recovering byproduct molybdenum at a new plant at Saladico in 1976. The plant has the capacity to produce 2 500 tonnes of molybdenum in concentrate a year. Chilean production is expected to continue to increase with output rising to 13 000 tonnes in 1978 and to 15 000 tonnes in 1980. Several companies, including Placer Development, were actively exploring for molybdenum during the year.

Iran. Molybdenum will be recovered as a byproduct of copper from the Sar Chesmeb copper deposit. Mining is scheduled to commence in 1978 and when production reaches rated capacity, an estimated 1 500 to 2 000 tonnes of molybdenum in concentrate will be recovered. The ore averages 0.03 per cent MoS_2.

U.S.S.R. Molybdenum is one of the few mineral commodities in which the U.S.S.R. is not self-sufficient. Production in 1976 is estimated to be some 9 300 tonnes of molybdenum in concentrate and is expected to increase to 10 700 tonnes by 1980. This increase will not affect eastern Europe's position as a net importer.

Table 6. Estimated world[1] consumption of molybdenum by end use, 1976

	(%)
Alloy steels[2]	48
Stainless steels	21
Tool steels	9
Chemicals and lubricants	8
Cast iron[3]	7
Non-ferrous alloys	3
Metal	3
Miscellaneous	1

Source: AMAX Inc., 1976 Annual Report.
[1]Excludes U.S.S.R., eastern Europe and the People's Republic of China. [2]Includes HSLA steels. [3]Includes steel mill rolls.

Consumption

The iron and steel industry is the largest single consumer of molybdenum, accounting for 85 per cent of total consumption in 1976 (Table 6). Of the molybdenum consumed, about 65 per cent is used as the oxide, 20 per cent as ferromolybdenum, 5 per cent as metal, and 10 per cent as molybdenum disulphide and other chemicals. Molybdic oxide is used primarily in the iron and steel industry, although in a purified form it can be used in the production of catalysts and other chemicals. Ferromolybdenum is again used principally in the iron and steel industry but small amounts are also used in the production of non-ferrous alloys and some special alloys such as permanent magnet alloys. Molybdenum metal is used as an addition agent in iron and steel and in non-ferrous alloys, as well as in the production of mill products. Molybdenum disulphide is used primarily in the manufacture of lubricants, and other molybdenum chemicals are used in a variety of forms as reagents and catalysts.

When added to iron or ordinary carbon steel, molybdenum improves the following properties of the iron and steel: tensile strength, creep resistance, corrosion resistance, hot strength, toughness, and hardenability. Molybdenum also promotes uniformity of these properties through iron and steel, even in relatively thick sections, because of its excellence as a grain refiner. With the exception of tool steels and some stainless steels, the molybdenum content of alloy steels is generally less than one per cent.

The major users of molybdenum-bearing steel are: the transportation industries, the mining and agricultural industries, the construction industry, and industries involved in the working of metal, wood and plastics; the energy and energy-related industries, the chemical and food processing industries, electric utilities and plants involved in the generation or transfer of heat. In the transportation industries, molybdenum-alloy steels are used in structural members and in parts subject to high stress, such as camshafts, differentials and gears. In the mining and agricultural industries, molybdenum-alloy steels are widely used in machinery and equipment that is subject to hard wear. In the construction industry, these steels are used as structural steels and in the metal, wood and plastics industries, molybdenum tool steels are used in the cutting and shaping of these materials. Molybdenum-alloy steels are used in the energy and energy-related industries for oil and gas transmission lines, well casing and in petroleum refineries where equipment is subject to corrosive media and/or high temperatures. In the chemical and food-processing industries, molybdenum-alloy steels are used in environments where corrosive media and/or high temperatures are encountered, or where high purity is required. Molybdenum-alloy steels also find wide usage in areas where continued high-temperature service is required, such as electrical utilities and boiler plants. In these areas, molybdenum-bearing steels are used in equipment such as heat exchangers, turbines, condensers and superheaters and in structural components such as piping and tubing and boilers.

Table 7. Estimated new production, mine closures and change in demand, 1977-1981

	1977	1978	1979	1980	1981
	(000 tonnes contained Mo)				
Output from new mines					
U.S.	8.50	14.50	19.00	21.50	23.75
Canada	0.25	0.25	0.25	0.25	2.50
Chile[1]	—	2.00	2.00	4.00	4.00
Iran	—	0.50	1.50	2.00	2.00
Other free market	—	—	—	—	—
Total	8.75	17.25	22.75	22.75	32.25
Production lost from closures					
U.S.	—	—	—	—	5.00
Canada	—	—	—	1.00	1.00
Other free market	—	—	—	—	—
Total	—	—	—	1.00	6.00
Net change in supply from 1976	+8.75	+17.25	+22.75	+26.75	+26.25
Increase in demand over 1976	5.00	12.00	18.00	25.00	32.00
Net change in supply-demand balance	+3.75	+5.75	+4.75	+1.75	−5.75

Source: Department of Energy, Mines and Resources, Ottawa.
[1] Increased byproduct recovery.
— Nil.

Molybdenum is added to non-ferrous alloys primarily for its ability to increase hot strength and corrosion resistance. Molybdenum-containing non-ferrous alloys are used in such areas as jet engines and chemical processing equipment. Molybdenum metal is used primarily because of its high melting point, hot strength, corrosion resistance and low coefficient of expansion. Molybdenum metal is used in the electrical and electronic industries for applications such as electric furnace elements, electrical contacts, power transistors, rectifiers and filament supports in incandescent light bulbs. Molybdenum metal is also used in the aerospace industry in such applications as missile nozzles.

Molybdenum compounds are widely used as catalysts, reagents and pigments, and in lubricants. Molybdenum compounds can function as catalysts or as activators and promoters for other catalysts. Molybdenum catalysts are used in such areas as the cracking and reforming of petroleum fractions, the synthesis of ammonia from nitrogen and hydrogen, and the cracking of acetone and ketone. Molybdenum compounds are particularly useful in the refining of petroleum and natural gas where traces of sulphur frequently contaminate other catalysts, but not those of molybdenum. Molybdenum compounds are also used in ceramics to promote the adherence of enamels to steels, as a pigment in paints, as a dye for natural furs and skins, as laboratory reagents, as corrosion inhibitors and as flame and smoke retardants for plastics. Molybdenum disulphide of high purity is used as a lubricant and can either be added to greases or oils or used directly as a dry film or solid lubricant. Molybdenum disulphide lubricants are used throughout industry as lubricants for such items as automobiles and industrial machinery.

Prices

There were three price increases during the year. The first two, one in March and one in August, were initiated by AMAX. The last, in December, was rather surprisingly initiated by Duval Sierrita Corporation, the second-largest producer in the United States. All producers, including AMAX, followed Duval's lead early in 1977. At year-end, prices in U.S. dollars a pound contained molybdenum stood at:

Concentrate	\$3.45	fob mine
United States		
Oxide	\$3.82	fob roaster
briquettes	\$3.90	fob plant
ferromolybdenum	\$4.43	fob plant
Europe		
oxide	\$4.00	fob Antwerp
ferromolybdenum	\$4.70	fob Luxembourg
Japan		
oxide	\$3.97	cif Japanese port
ferromolybdenum	\$4.64	cif Japanese port

Overall, prices rose more than 30 per cent during the year.

Outlook

Molybdenum is expected to remain generally in short supply through to the mid-1980s. Production from new mines is not expected to be sufficient to cover the shortfall in supply that existed in 1976, plus the anticipated increase in demand and the expected losses in production resulting from mine closures (Table 7). The net addition to supply from new mines, although positive in 1977 to 1980 is not sufficient to cover the deficit of 6 000 tonnes in 1976. A further period of severe shortages is expected to begin in 1981 and will not be relieved until the mid-1980s when new mines are expected to come into production in Canada and the United States.

With primary mines operating at, or near, rated capacity, little increase in supply can be expected from existing producers. The only factor that could ease this situation would be increased byproduct production in the United States. In 1976, byproduct production was an estimated 7 000 to 8 000 tonnes a year below capacity levels. If this capacity was fully utilized, the expected shortages from 1977 to 1980 would be eliminated and the supply shortage in the early 1980s would be considerably reduced. However, no significant recovery in copper markets is seen before 1979 or 1980 at the earliest and, consequently, byproduct production will not approach capacity levels. Any disruption in production from primary molybdenum mines will further aggravate the expected shortages. With these mines operating near capacity for almost two years, it is likely that there will be some temporary production losses in this period.

The continuing supply shortages will place strong pressure on prices, and prices are consequently expected to increase in real terms through the mid-1980s at least. Price increases can be expected in 1977-78 and in 1980-81. These price increases should be an incentive to bringing on the necessary production capacity to satisfy demand in the shortest possible time.

Tariff profile (most favoured nation)

Item	European Economic Community	United States	Japan (GATT)	Canada
Molybdenum ores and concentrates	Free	12¢ per lb on Mo content	–	Free
A. Quota	–	–	Free	–
B. Other	–	–	7.5%	–
Molybdenum oxides and hydroxides	8%	10¢ per lb on Mo content +3%	–	15%
A. Molybdenum trioxide	–	–	5%[1]	–
B. Other	–	–	10%[2]	–
Ferromolybdenum	7%	10¢ per lb on Mo content +3%	7.5%[3]	5%
Sodium molybdate	11.2%	10¢ per lb on Mo content +3%	7.5%[3]	15%
Ammonium molybdate	11.2%	10¢ per lb on Mo content +3%	7.5%[3]	15%
Cobalt molybdate	11.2%	10¢ per lb on Mo content +3%	7.5%[3]	15%
Molybdenum carbide	9.6%	10¢ per lb on Mo content +3%	5%[4]	5%
Molybdenum				
A. Unwrought: powder	6%	10¢ per lb on Mo content +3%	5%[4]	Free
other	5%	10¢ per lb on Mo content +3%	5%[4]	Free
Waste and scrap	5%	10.5%[5]	5%[4]	Free
B. Wrought:				
Bars, angles, plates, sheets	8%	12.5%	7.5%[3]	Free
Wire	8%	12.5%	7.5%[3]	Free
C. Other	10%	12.5%	7.5%[3]	Free

Sources: Official Journal of the European Communities, Common Customs Tariff; Tariff Schedules of the United States Annotated; Customs Tariff Schedules of Japan, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa.
[1]Temporarily reduced to 4%. [2]Temporarily reduced to 8%. [3]Temporarily reduced to 6%. [4]Temporarily reduced to 4%. [5]Temporarily suspended. GATT – General Agreement on Tariffs and Trade.

Natural Gas

W.G. LUGG

The Canadian natural gas picture improved somewhat in 1976 as gross additions to new reserves exceeded production by 37 billion cubic metres (m^3) (1.3 tcf — trillion cubic feet). Although most of the additions to reserves occurred in the Mackenzie Delta region, additions to reserves in Alberta more than offset its production.

Production of natural gas increased only marginally but revenue from the sale of natural gas was at an all-time high of $3 512 million reflecting substantial increases in both export and domestic natural gas prices. Expenditures for exploration and development, including royalty payments, escalated by $1 369 million to $5 444 million; most of the expenditures were made in western Canada and most of this was directed toward natural gas exploration and development.

Exploration was at an all-time high and drilling exceeded the previous record level established in 1973. Stimulated by escalating crude oil and natural gas prices and provincial government drilling incentives, exploratory and development drilling increased. Both the number of wells and metres drilled increased by approximately 33 per cent. Although activity in the frontier regions declined, exploration in the Rocky Mountain foothills of Alberta and several successful follow-up wells to 1975 discoveries substantially increased Alberta's proven reserves.

Net reservoir withdrawals recorded a nominal growth rate of 0.2 per cent to 87 546 million m^3 or 239 million m^3 a day (3.09 tcf or 8 444 MMcf/d). Both export and domestic markets increased in 1976 in contrast to the previous year when export markets declined and growth in the domestic market was minimal. Export sales increased by 0.52 million m^3 a day (18.36 MMcf/d) to 62.06 million m^3 a day (2 605 MMcf/d) while demand in the domestic market also rose by 3.57 million m^3 a day (126 MMcf/d) to 38 835 million m^3 (1.37 tcf). Imports from the United States, never very large, decreased in 1976, averaging 314 thousand m^3 a day (11 MMcf/d).

Gross additions to marketable reserves increased by 109 299 million m^3 (3.86 tcf) mainly because of additions in the Mackenzie Delta and the foothills area of Alberta. By the end of 1976 natural gas reserves had risen to 1 642 035 million m^3 (58.28 tcf), 36 830 million m^3 (1.3 tcf) more than in 1976.

Pipeline construction increased in 1976, chiefly because of record levels in gathering-line construction that resulted from a late upsurge in gas field development. The hearings conducted by the National Energy Board (NEB) relating to proposed northern pipeline construction continued in 1976 with no final decision reached. Three proposals were being considered at year-end; one by Canadian Arctic Gas Study Limited (CAGSL) and two by Foothills Pipe Lines Ltd. A record number of new gas plants were constructed in 1976, although most of them were small-capacity projects.

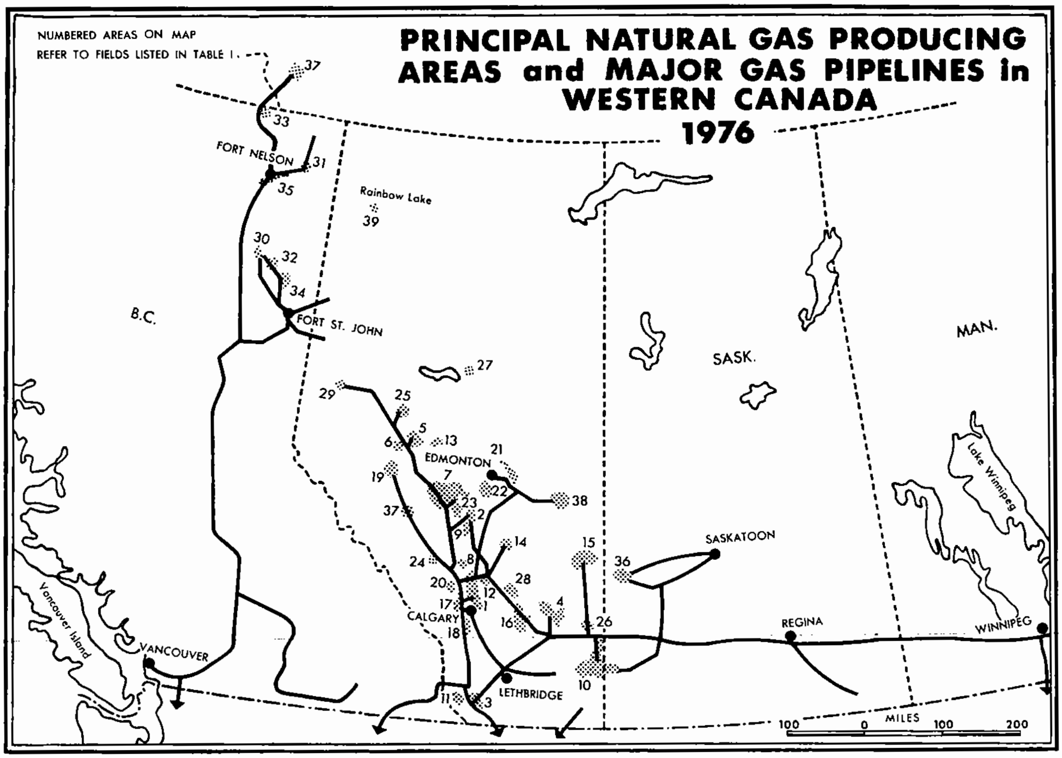
Outlook

The outlook for the Canadian natural gas industry brightened to some degree in 1976, largely because the prospects for proving up significant amounts of new gas reserves in Alberta and British Columbia have greatly improved. The unfavourable trend that prevailed in 1972 and 1973, when additions to reserves fell below annual production, has been reversed. Changing royalties and tax structures, together with increased prices and provincial drilling incentives, have been responsible for this reversal. Domestic gas prices have continued to move closer to the still-increasing price of Canadian oil, and taxation burdens have eased to some degree. As a result, producers are continuing to develop the shallow gas prospects in the southern and northern areas of Alberta and exploratory drilling is intensifying in the foothills areas of both northeastern British Columbia and Alberta. Therefore, in the short term there is no immediate danger of shortages of natural gas. During 1977 gross new production of natural gas is expected to increase by about 4 per cent to 103 358 million m^3 (3.64 trillion cubic feet) a year. Notwithstanding the improved prospects for finding new gas supplies in the established producing areas of western Canada, present indications are that it will be difficult to meet the country's on-going requirements from these sources much beyond the mid-1980s and still meet export commitments. The longer-term demand

Table 1. Canadian natural gas fields producing 281 740 cubic metres[1] or more, 1975-76

(numbers in brackets refer to map locations)	1975 (thousand cubic metres)[2]	1976 (thousand cubic metres)[2]
Alberta		
Kaybob South (25)	7 028 965	6 002 235
Waterton (11)	4 024 939	4 080 651
Crossfield (1)	3 950 717	3 663 681
Edson (19)	2 974 134	2 795 709
Medicine Hat (10)	2 783 337	3 252 704
Strachan (24)	2 749 747	2 486 844
Ricinus West (24)	2 402 555	2 709 110
Westerose South (2)	2 259 377	1 909 777
Brazeau River (37)	2 184 677	1 903 012
Harmattan Elkton (8)	1 996 983	2 011 203
Harmattan East (8)	1 819 166	1 941 003
Dunvegan	1 445 946	1 409 778
Homeglen-Rimbey (9)	1 391 778	1 274 703
Carstairs (12)	1 366 931	1 259 169
Gilby (9)	1 340 908	1 394 529
Crossfield East (1)	1 271 347	1 179 876
Nevis (14)	1 260 207	1 097 728
Jumping Pound West (17)	1 177 962	1 322 348
Marten Hills (27)	1 132 298	1 254 739
Provost (15)	1 129 465	1 080 917
Windfall (5)	996 567	996 085
Cessford (4)	990 354	882 374
Minnehik-Buck Lake (23)	988 208	858 756
Wildcat Hills (20)	981 661	880 202
Pembina (7)	942 636	976 632
Ferrier (8)	934 793	876 449
Sylvan Lake (2)	879 987	860 388
Bonnie Glenn (22)	819 349	1 460 839
Alderson (10)	814 851	930 322
Lone Pine Creek (1)	739 840	642 731
Pine Creek (6)	720 065	723 676
Viking Kinsella (38)	730 373	538 671
Swan Hills (13)	716 229	644 049
Judy Creek (13)	695 412	637 554
Kaybob (25)	689 434	570 877
Rainbow (39)	665 575	661 839
Swan Hills South (13)	623 196	676 323
Ricinus	613 259	777 753
Westlock (21)	600 643	611 499
Ghost Pine (28)	595 118	438 272
Quirk Creek	592 600	543 506
Carson Creek (13)	549 124	592 895
Burnt Timber (20)	543 154	486 090
Lookout Butte (3)	473 069	386 362
Bantry	468 746	505 024
Jumping Pound (17)	455 680	356 386
Beaverhill Lake	452 673	177 887
Wimborne (12)	447 663	393 964
Warwick	428 169	407 505
Hussar (16)	405 437	354 630
Fort Saskatchewan (21)	374 141	299 604
Leduc — Woodbend (22)	372 112	361 250
Bindloss (26)	355 884	308 864
Bruce	335 594	257 963
Olds (12)	311 678	299 407
Medicine River	311 817	277 789
Countess (16)	310 840	312 469
Carson Creek North (13)	308 908	281 534
Wayne-Rosedale (3)	302 823	282 622
Whitecourt	302 697	292 238
Bigstone (25)	300 868	310 142
Simonette	293 820	212 920
Craigend (27)	285 684	253 658
Wizard Lake	283 913	199 356
Willesden Green	277 232	284 501
Princess	230 376	504 767
Hairy Hill	132 774	384 783
Coleman	49 922	301 308
British Columbia		
Clarke Lake (35)	2 758 248	2 260 294
Yoyo (31)	1 883 138	2 018 403
Sierra (31)	985 206	889 791
Laprise Creek (30)	732 382	579 906
Rigel (34)	503 665	418 288
Buick Creek (32)	388 222	310 641
Jedney (30)	361 531	301 791
Stoddart (34)	311 940	288 779
Beaver River (33)	309 214	192 335
Nig Creek (32)	294 024	261 795
Northwest Territories		
Pointed Mountain (37)	870 316	947 543

Sources: Provincial government reports.
[1] $m^3 \times 10^3$ = thousand cubic metres [2] 14.65 pounds per square inch absolute.



will therefore have to be met from supply sources in the frontier areas. To date, exploration in these areas has been encouraging and substantial reserves have been found, particularly in the Arctic islands and Mackenzie Delta. However these new supplies are well below the amount required to justify the costly infrastructure required to transport this gas to southern markets. Providing additional supplies are discovered in frontier regions during the next two years, it would still be optimistic to presume that production would be marketed much before the late 1980s. Because of the remoteness of these newly discovered resources, the costs of developing and moving them to consuming centres will necessarily be high. These costs will be assumed ultimately by the consumer, who will have to pay considerably more than the current retail prices, which also have risen substantially in recent years.

In summary, marketers will likely obtain adequate supplies of new gas in the short and medium term. In the longer term, supply will hinge on the industry's ability to improve its discovery rate in the frontier areas.

Production

In 1976 net withdrawals of natural gas amounted to 87 546 million m^3 or 239 million m^3 a day (3.09 tcf or 8443 MMcf/d) for an 0.2 per cent increase over 1975 withdrawals. Alberta continued to be the main producing province, accounting for 86 per cent of Canada's marketable gas production. British Columbia accounted for more than 12 per cent of the Canadian total, with the balance coming from four other provinces and the Northwest Territories. The Kaybob South field continued to be the largest producer in Alberta and the Clarke Lake field in northeast British Columbia remained that province's most-productive field. Production from the Beaver River field in British Columbia and the Pointed Mountain field in the Yukon Territory continued to decline. Because of reservoir damage, production from both these fields began to decline at a relatively early stage in their production history. To date the operators have been unable to restore production to normal levels and as a result two fields which used to be major contributors to overall provincial production now serve only a minor role.

In Alberta no new large fields came on stream in 1976, although a record number of small fields were placed on production. In 1977 and 1978 it is anticipated that three major gas fields recently discovered in the Alberta foothills will also likely be placed on production.

Table 2 shows the amount of gas injected into reservoirs, either as a conservation measure to increase the ultimate recovery of liquid hydrocarbons, or as part of distributors' storage operations. The Kaybob South field is an example of a conservation scheme to maximize ultimate recovery of the liquid constituents of field gas. Here, gas is produced and processed to remove the liquid hydrocarbons and sulphur, after which most of the residual gas is reinjected to maintain pressure in the original producing reservoir. This operation is to ensure the maximum possible recovery of natural gas liquids before the reservoir is depleted by the sale of the gas. Similarly, natural gas may temporarily be reinjected into producing oil reservoirs, thereby maintaining reservoir pressure to maximize production of crude oil where this is possible. The volumes shown as distributors' storage represent gas which is stored by gas utilities during low-demand periods, usually in summer, and later withdrawn as required to meet peak demands in winter. This helps to level out the utilities' demand on the trunk carriers over the year. In Alberta and Ontario most of the gas is stored in former producing fields which have been depleted. However, in Saskatchewan much of the storage is in large man-made subsurface caverns that have been leached from salt beds specifically to provide storage facilities near major consuming areas.

Exploration and development

Alberta. Both the number of wells and metres drilled increased substantially in Alberta in 1976. The increase is attributable to increased industry activity in exploring for and developing the shallow gas-producing trends in southern and northern Alberta. Drilling statistics show development drilling increased 32 per cent to 2.9 million metres and exploratory drilling 34 per cent to 1.96 million metres. Successful gas completions increased by 1 271 wells to 3 193 in 1976.

The foothills of the Rocky Mountains were again a prime target for industry exploratory activity in 1976. Following the three major gas discoveries made in the Burnt Timber, Wilson Creek and Limestone Mountain regions in 1975 several follow-up wells have been drilled on these discoveries and early indications are that recoverable reserves of natural gas in the area will exceed 28 328 million m^3 (1 tcf). At the present time Shell Canada Limited, one of the principal operators in the region, has contracted for a major expansion of its Burnt Timber gas processing plant and announced plans for the construction of a new large processing plant in the same area. Elsewhere in the foothills a Devonian reef gas discovery was made in the Pinto

Table 2. Pressure maintenance projects and storage of natural gas in Canada, 1975-76

	1975 Input	1976^p Input		1975 Input	1976^p Input
	(000 cubic metres)			(000 cubic metres)	
Alberta					
Aerial	6 132	8 174	Redwater	4 101	—
Ante Creek	43 173	42 826	Ricinus	404 676	398 122
Bellshill Lake	13 571	12 556	Rowley	1 679	—
Bigstone	4 846	1 257	Swan Hills South	412 824	337 323
Bonnie Glenn	418 781	1 055 787	Turner Valley	—	9 347
Carson Creek	175 427	84 964	Waterton	416 895	421 009
Carstairs	22 023	59 666	Westerose South	116 306	—
Crossfield East	26 943	26 522	Willesden Green	288 140	310 972
Duhamel	12 265	14 635	Windfall	957 428	977 553
Golden Spike	269 548	149 052	Wizard Lake	443 722	390 465
Harmattan East	785 060	1 005 437	Total (14.65 psia)	10 269 153	10 294 813
Harmattan Elkton	1 267 580	1 230 932	Total (14.73 psia)	10 269 475	10 295 134
Joarcam	52 725	51 388			
Judy Creek	825	—			
Kaybob South	3 484 569	3 081 038	**Ontario**	3 531 850	2 989 300
Leduc-Woodbend	157 172	146 696			
Mitsue	40 829	22 922	**Saskatchewan**	236 656	372 683
Pembina	38 157	27 799			
Rainbow	330 129	350 677	Total Canada		
Rainbow South	73 627	77 694	(14.73 psia)	14 037 981	13 657 117

Sources: Provincial government reports.
^{p}Preliminary; — Nil.

Table 3. Canada, production of natural gas, 1975-76[1]

	1975		1976[p]	
	million cubic metres	$ 000	million cubic metres	$ 000
Gross new production				
New Brunswick	3		3	
Quebec	1		. . .	
Ontario	310		153	
Saskatchewan	1 961		1 902	
Alberta	84 714		85 466	
British Columbia	12 275		11 805	
Northwest Territories and Yukon	57		54	
Total, Canada	99 321		99 383	
Waste and flared				
Saskatchewan	221		221	
Alberta	1 045		922	
British Columbia	104		130	
Northwest Territories and Yukon	48		45	
Total, Canada	1 418		1 318	
Reinjected				
Alberta	10 306		10 445	
British Columbia	77		74	
Northwest Territories and Yukon	—		—	
Total, Canada	10 383		10 519	
Net withdrawals				
New Brunswick	3	55	3	60
Quebec	1	8	. . .	2
Ontario	310	6 508	153	6 200
Saskatchewan	1 739	10 449	1 682	8 907
Alberta	73 364	1 405 247	74 099	2 328 026
British Columbia[2]	12 094	98 358	11 601	151 936
Northwest Territories and Yukon	9	36	9	184
Total, Canada	87 520	1 520 661	87 547	2 495 315
Processing shrinkage				
Saskatchewan	39		41	
Alberta	11 164		10 824	
British Columbia	1 263		1 146	
Total Canada	12 466		12 011	
Net new supply, Canada	75 054		75 536	

Sources: Statistics Canada and provincial government reports.
[1]14.73 psia; [2]British Columbia total includes Pointed Mountain gas produced in Northwest Territories and Beaver River gas produced in the Yukon but processed in British Columbia.
[p]Preliminary; — Nil; . . . Insignificant.

Table 4. Canada, production, trade and total sales of natural gas, 1966-76

		Net Withdrawals	Imports	Exports	Sales in Canada
1966	000 cubic metres	38 011 236	1 233 701	12 074 000	18 002 757
	$	179 183 990	17 592 370	108 749 931	416 212 202
1967	000 cubic metres	41 690 777	1 497 740	14 310 223	19 779 162
	$	197 983 450	19 914 301	123 663 828	454 722 005
1968	000 cubic metres	47 939 226	2 499 304	16 944 121	21 693 086
	$	225 263 658	35 392 758	153 751 558	490 767 434
1969	000 cubic metres	56 027 884	1 068 886	18 974 434	23 885 042
	$	262 332 030	16 025 449	176 187 766	537 186 938
1970	000 cubic metres	64 505 573	336 473	21 758 969	25 989 118
	$	315 099 792	5 123 896	205 988 180	582 316 948
1971	000 cubic metres	70 791 941	453 535	25 581 486	28 365 477
	$	342 548 891	7 021 000	250 719 000	641 898 026
1972	000 cubic metres	82 520 334	446 434	28 527 660	32 457 958
	$	388 500 342	7 629 000	306 843 000	740 382 930
1973	000 cubic metres	88 367 585	416 410	29 203 534	34 826 520
	$	451 853 205	7 793 000	350 745 000	797 855 930
1974	000 cubic metres	86 272 607	261 405	27 214 927	37 231 875
	$	723 766 000	5 777 000	493 640 000	980 395 000
1975	000 cubic metres	87 519 740	295 940	26 896 300	37 526 031
	$	1 520 661 000	7 830 000	1 092 168 000	1 307 287 000
1976[p]	000 cubic metres	87 546 283	253 674	27 026 195	38 834 919
	$	2 495 315 000	8 818 000	1 616 490 000	1 895 543 000

Source: Statistics Canada.
Figures in Tables 4 and 12 differ for imports and exports because of different reporting procedures and timing.
[p] Preliminary.

region of western Alberta about 20 miles west of the Berland River field. Early indications are that this is a substantial discovery although its true significance will only be known after a more complete evaluation.

In northwestern Alberta a major new shallow gas trend continued to develop near the scene of the Keg River Oil discoveries of 1965. Several discoveries were made in the Bluesky formation of Cretaceous age in 1974 and since then several successful follow-up wells have been drilled, expanding the known limits of the productive area. Based on current data, the Alberta Energy Resources Conservation Board (AERCB) estimates recoverable reserves from this producing trend to be 65 136 million m^3 (2.3 tcf). Only a short time ago, natural gas from low-permeability reservoirs in this relatively remote area would have been considered economically unattractive by the producing industry. With increased prices, however, production of the gas has become economic and development of the area is proceeding.

In the Suffield Block of southeastern Alberta several "deep rights" exploratory wells were drilled in 1976 and to date two of these were classed as multiple-zone heavy oil and gas discoveries, one as a heavy oil discovery, one as a single-zone gas discovery and one as a dual-zone gas discovery. Further exploratory and development drilling is contemplated in 1977 to determine the extent of these discoveries in terms of producibility and reserves. It should be recalled that 76 464 million m^3 (2.7 tcf) of proven reserves were discovered in the Suffield Block by an Alberta government-sponsored drilling program in 1974, primarily from the Milk River producing horizon. This producing zone of southwest Alberta is estimated to contain over 226 560 million m^3 (8 tcf) of gas by the AERCB.

Province-wide, there were about 200 single-well gas discoveries made in 1976. Among the most important of these were the recent discoveries in the Pass Creek area of central-west Alberta. Several significant gas finds have been reported in this region in both the Viking and Gething formations. In the Stohlberg region of central-west Alberta several noteworthy gas discoveries were made in Mississippian horizons late in 1976. Excellent flow rates have been established on drill-stem tests of the producing horizons and although it is too early to predict the true significance of the find, indications are that a new Mississippian gas-producing trend is beginning to unfold. In south-central Alberta a dual-zone gas strike was recorded in the Carseland region. The discovery well indicated commercial quantities of natural gas on drill-stem tests of both the Belly River and Viking formations. The new discovery is located 23 kilometres from the Herronton field and 40 km south-east of Calgary.

As in previous years, much of the development drilling was confined to the shallow gas trends of the southern areas of the province. Elsewhere, the Quirk Creek field, discovered in 1973, was placed on production by the drilling of five development wells. The operating company has scheduled several more development wells for this field as its maximum producing potential is phased in. In northeast Alberta the Wandering River gas field was placed on production. Thirty-seven development wells were drilled and 102 km of gathering line were installed. The gas has been contracted for 20 years for use in the tar sands operations near Athabasca.

British Columbia

Total metres drilled and the number of wells completed increased substantially in 1976. Both exploratory and development work increased as aggregate metres drilled was up by 120 per cent to 283 091 metres. The exploratory companies in British Columbia completed the year with a total of 175 wells drilled, which included 86 wells reported as potential gas producers. This is a sharp increase from activity levels in 1975 which established an all-time low, and this increase can be directly attributed to higher gas prices paid to producers.

The highlight of industry activity in British Columbia was successful exploratory and development drilling in the Sukunka-Grizzly Valley trend which is located south of Dawson Creek, adjacent to the Alberta border. Exploration began in this area in 1964 but it was not until recently that sufficient reserves had been proven to justify further development. Unofficially, recoverable reserves of natural gas in these fields are estimated to be over 14 160 million m^3 (.5 tcf) and Westcoast Transmission Company Limited has announced that it will proceed with a $100 million investment in gas processing and transmission facilities to bring the Grizzly fields into production in two years.

Since the Helmet gas field in the northeastern corner of British Columbia came on production in 1975 and was connected to markets via an extension to Westcoast Transmission Company Limited's main line, exploration has increased in this area and met with some success. Several gas discoveries were reported in this region in 1976 but before their true significance is known they will have to be more fully evaluated.

Yukon Territory, Northwest Territories and Arctic islands. In the territorial regions exploration fell off considerably in 1976 and there was a lower success ratio. Twenty-seven wells were drilled for a total of 83 807 metres compared to 43 wells and 113 218 metres in 1975.

In the Mackenzie delta, Gulf Oil Canada Limited drilled several successful gas completions in the Parsons Lake field and considerably extended the as-yet-undefined limits of the producing trend. In addition, Gulf made an oil and gas discovery just east of the Parsons Lake field in the same producing zones. The discovery well is on a feature separate from the Parson's Lake field and seismic data suggests the structure

Table 5. Canada, liquids and sulphur recovered from natural gas, 1966-76

	Propane	Butane	Condensate Pentanes Plus	Sulphur
	(cubic metres)	(cubic metres)	(cubic metres)	(tonnes)[1]
1966	1 983 151	1 300 062	4 668 713	1 757 209
1967	2 249 166	1 482 987	4 887 492	2 203 448
1968	2 520 818	1 656 959	5 278 723	3 090 925
1969	2 831 090	1 778 223	6 126 421	3 773 919
1970	3 382 352	2 099 228	7 019 513	4 309 041
1971	3 851 547	2 455 929	7 456 208	4 628 393
1972	4 696 619	3 093 703	9 671 111	6 723 409
1973	5 315 544	3 567 161	9 867 029	7 115 881
1974	5 268 092	3 519 638	9 413 046	6 950 327
1975	5 531 963	3 642 717	8 816 323	6 487 466
1976[p]	5 404 932	3 582 938	7 786 085	6 497 627

Sources: Statistics Canada and provincial government reports.
[1]The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
[p]Preliminary.

Table 6. Wells drilled by province, 1975-76

	Oil		Gas		Dry[1]		Total	
	1975	1976[p]	1975	1976[p]	1975	1976[p]	1975	1976[p]
Western Canada								
Alberta	660	550	1 922	3 193	1 064	1 229	3 646	5 042
Saskatchewan	105	154	85	16	77	87	267	257
British Columbia	2	13	31	86	47	76	80	175
Manitoba	2	3	—	—	5	13	7	16
Yukon and Northwest Territories & Arctic Islands	3	4	6	9	34	18	43	31
Westcoast offshore	—	—	—	—	—	—	—	—
Subtotal	772	724	2 044	3 304	1 227	1 423	4 043	5 521
Eastern Canada								
Ontario	4	3	68	67	66	74	138	144
Quebec	—	—	—	2	3	2	3	4
Atlantic Provinces	—	—	—	—	7	2	7	2
Eastcoast offshore	—	—	—	—	9	11	9	11
Hudson Bay offshore	—	—	—	—	—	—	—	—
Subtotal	4	3	68	69	85	89	157	161
Total Canada	776	727	2 112	3 373	1 312	1 512	4 200	5 682

Source: Canadian Petroleum Association.
[1]Includes suspended and abandoned wells, but excludes miscellaneous wells.
[p]Preliminary; — Nil.

Table 7. Metres drilled in Canada for oil and gas by provinces, 1975-76

	Exploratory[1]		Development[2]		All Wells[3]	
	1975	1976[p]	1975	1976[p]	1975	1976[p]
Alberta	1 457 263	1 964 336	2 191 907	2 907 372	3 649 170	4 871 708
Saskatchewan	89 230	130 526	108 648	99 144	197 878	229 670
British Columbia	84 618	147 967	43 870	135 124	128 488	283 091
Manitoba	3 628	10 411	3 059	3 103	6 687	13 515
Territories and Arctic Islands	86 374	58 107	26 844	25 700	113 218	83 807
Westcoast offshore	—	—	—	—	—	—
Total Western Canada	1 721 113	2 311 347	2 374 328	3 170 444	4 095 441	5 481 791
Ontario	37 090	35 321	28 611	37 951	65 701	73 272
Quebec	3 037	8 543	—	—	3 037	8 543
Atlantic Provinces	17 134	3 271	—	—	17 134	3 271
Eastcoast offshore	26 313	22 793	—	—	26 313	22 793
Total Eastern Canada	83 574	69 928	28 611	37 951	112 185	107 879
Total Canada	1 804 687	2 381 275	2 402 939	3 208 395	4 207 626	5 589 670

Source: Canadian Petroleum Association.
[1]Exploratory total includes new field wildcats, new pool wildcats, exploratory part of deeper pool tests, shallower pool tests, outposts, and stratigraphic tests. [2]Development total includes remainder of drilling for deeper pool tests not included in exploratory total. [3]All wells total excludes potash wells and miscellaneous wells.
[p]Preliminary; — Nil.

is very complex. Only further drilling will determine if the discovery has field potential.

Offshore in the Beaufort Sea, Dome Petroleum Limited commenced its multiwell drilling program in 1976 utilizing three specially designed, ice-reinforced drillships. Before the abbreviated drilling season had concluded Dome had apparently made a significant gas discovery at an intermediate depth. In the interests of environmental safety, Dome suspended drilling at the well before the gas-bearing zone could be fully evaluated and before it could be determined if there was an associated oil leg beneath the gas-bearing zone. The well tested some gas (not measured) from the 3 040-metre level and it will be completed and evaluated during the 1977 summer drilling season. Surface casing was installed during 1976 for three more offshore wells which are scheduled to be drilled during the summer of 1977.

To summarize; the level and results of exploratory effort in the Mackenzie Delta in 1976 were disappointing, although some success was obtained. Although there has been no official estimate made of gas reserves in the delta, in the light of evidence given at recent National Energy Board northern pipeline hearings best estimates suggest total proved and probable reserves are 198 240 million m³ (7 tcf). The bulk of the reserves are located in the Taglu and Niglintgak fields.

In the Arctic islands, Panarctic Oils Ltd. made two significant gas discoveries in April 1976. The first was a major northwestward extension to the Hecla gas field off the Sabine Peninsula, Melville Island. The well was drilled 24 km offshore in 30 metres of water from an artificially-thickened ice pad. The Hecla field is now over 40 km long and is estimated to contain upwards of 99 050 m³ (3.5 tcf) of natural gas. The second gas discovery, called Jackson Bay, was drilled six km offshore from Ellef Ringnes Island in 60.8 metres of water about midway between Panarctic's King Christian Island gas field and the gas field at Kristoffer Bay on Ellef Ringnes Island. The well was drilled on a separate structure from those of the two previous discoveries in the area and is reported to have a net pay of 177 metres and high reservoir pressures.

In November of 1976 Sun Oil Company Limited and Global Arctic Islands Limited announced farm-out agreement with a four-company group composed of Imperial Oil Limited, Gulf Oil Canada Limited, Panarctic Oils Ltd., and Petro-Canada Exploration Inc. Under terms of the agreement the four-company group has agreed to spend $80 million on exploration in return for a working interest in 133 billion m² (33 million acres) of Sun Oil's permit acreage in the Arctic islands.

Consultants to Panarctic Oils Ltd. estimated that natural gas fields discovered to the end of 1976 in the Canadian Arctic islands contained a "most likely" marketable reserve of just over 453 000 million m³ (16 tcf). However, a delineation well drilled in the Drake Point field early in 1977 was unsuccessful, and subsequently Arctic island reserve estimates were reduced to 339 600 million m³ (12 tcf).

Saskatchewan.

Although the number of wells drilled in Saskatchewan declined in 1976, metres drilled increased slightly over 1975. The number of wells drilled was reduced from 267 to 257, and metres drilled increased from 197 878 to 229 670.

Exploration activity in Saskatchewan, where there is a growing involvement by the Saskatchewan Oil and Gas Corporation (Saskoil), continued at a subdued pace in 1976.

Most of the exploratory and development drilling was confined to the southwest corner of the province where the productive shallow gas trends of Alberta and Saskatchewan are located. Although these trends continue to be enlarged, there were no noteworthy discoveries of new reserves in this area.

Eastern Canada

Drilling commenced offshore from the east coast in 1966 and since then 136 wells have been drilled, from which seven, and probably eight, oil and gas discoveries have been made. The two most important of these were made in 1973 and 1974 on the Labrador Shelf. The Bjarni-H81 well drilled in 1973 and the Gudrid well, drilled in 1974, both turned out to be significant discoveries. Two more potential gas discoveries were made on the Labrador Shelf in 1975. Work on both had to be suspended because of bad weather and the short drilling season. Both were re-entered, drilled to total depth and evaluated in 1976. One of these, Eastcan Snorri J-90, located about 1 126 km north of St. John's, Newfoundland, yielded significant flows of gas and condensate and is considered to be a potential commercial discovery. The other well, Karlsefni H-13, also penetrated a gas- and condensate-bearing reservoir but is not considered to be commercial at the present time.

On the Grand Banks and Scotian Shelf exploration has been declining, as results have been costly and disappointing. The only discoveries in this region have

Table 8. Canada, estimated year-end marketable reserves of natural gas, 1975-76

	1975	1976
	(million cubic metres)	
Alberta	1 276 972	1 285 415
British Columbia	192 702	188 541
Saskatchewan	25 282	23 859
Eastern Canada	7 507	8 277
Northwest Territories	102 742	135 943
Total	1 605 205	1 642 035

Source: Canadian Petroleum Association.

been made in the vicinity of Sable Island where the initial discovery was made in 1971 on the southwestern tip of the island. Six miles to the southwest a gas condensate discovery was made a year later and the third significant gas discovery was made 30 miles east of Sable Island when the Primrose N-50 well gave flows of gas with condensate from three separate zones. The other find was an oil discovery — the Cohasset D-42 well located 40 metres southwest of Sable Island.

In 1976, exploration on the Scotian Shelf was revitalized to some degree by Petro-Canada when it embarked on a multi-well drilling program which commenced early in the year. The program involves three separate exploration agreements with major oil companies that have been active in the east offshore area for several years. Cost of the Petro-Canada program is in the order of $20 million. Of the initial six wells drilled, only one well, Shell Petro-Canada Penobscot B-41 located 20 miles north of Sable Island, showed any promise. Shell, the operator, announced that several non-commercial oil zones were encountered. As a result, a follow-up well has been licenced by the Shell-Petrocan team, and should this well prove to be successful it is anticipated that a new drilling agreement will be formulated between the partners to delineate the structure and others in the vicinity.

In addition to its current $20 million drilling project on the Scotian Shelf with Shell, the company is engaged in another $25 million venture on Sable Island with the Mobil Oil Canada, Ltd, Texas Eastern Exploration of Canada Ltd. and the Texaco Exploration group.

Table 9. Canada, natural gas processing plant capacities by field 1976

Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced	Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced
	(million cubic metre/day)			(million cubic metre/day)	
Alberta					
Acheson	0.169	0.141	Crossfield (2 plants)	8.874	6.057
Alexander, Calahoo	1.014	0.986			
Atmore	0.281	0.281	Davey	0.225	0.225
			Dunvegan	6.762	6.621
Bantry (2 plants)	0.394	0.338			
Bashaw	0.338	0.338	East Crossfield (2 plants)	4.311	3.409
Bassano	0.225	0.225	East Rainbow Lake	0.507	0.310
Big Bend	0.563	0.563	Edson (2 plants)	10.678	9.607
Bigorary	0.084	0.056	Elnora	0.338	0.338
Bigstone	1.352	1.014	Enchant	0.141	0.141
Blacke Butte	0.282	0.282	Equity, Ghost Pine	0.451	0.423
Black Diamond	0.338	0.310			
Bonnie Glenn (2 plants)	5.296	4.676	Ferintosh	0.141	0.141
Boundary Lake South	0.479	0.366	Ferrier (2 plants)	3.099	2.535
Braeburn	0.169	0.141	Ferrier South	0.563	0.535
Brazeau River	5.522	4.817	Ferrybank	0.591	0.563
Brazeau South	1.859	1.690			
Bruce	0.845	—	Garrington (2 plants)	0.535	0.507
Burnt Timber	1.916	1.606	Ghost Pine	3.099	3.043
			Gilby (11 plants)	4.790	4.000
Cadomin	0.056	0.056	Gilby North	0.535	0.507
Calling Lake	0.507	0.507	Gold Creek	1.578	0.423
Carbon (2 plants)	4.564	4.423	Golden Spike	2.536	reinj
Caroline (2 plants)	1.493	1.267	Greencourt	0.845	0.789
Carson Creek	2.817	1.746			
Carstairs	9.410	7.888	Hanna	0.338	0.225
Cessford (6 plants)	6.057	5.860	Harmattan-Elkton (2 plants)	15.073	8.875
Cessford North	0.197	0.169			
Choice	0.281	0.281	Harmattan-Elkton South	0.141	0.113
Chip Lake	0.141	0.112	Hercules	0.085	0.085
Chigwell (3 plants)	0.310	0.281	Holmberg	0.338	0.338
Corbett Creek	0.254	0.254	Homeglen-Rimbey	11.918	10.058
Countess (2 plants)	1.267	1.211	Hotchkiss	0.507	0.507

Table 9 (cont'd)

Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced	Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced
	(million cubic metre/day)			(million cubic metre/day)	
Alberta (cont'd)			**Alberta (cont'd)**		
Hussar (3 plants)	3.240	2.958	Princess (2 plants)	0.451	0.423
Huxley	0.366	0.282	Provost (5 plants)	3.691	3.465
Innisfail	0.563	0.366	Quirk Creek	2.536	1.916
Joffre	0.225	0.141	Rainbow Lake (2 plants)	2.395	reinj
Judy Creek, Swan Hills (3 plants)	7.720	5.607	Redwater	0.620	0.225
			Retlaw	0.620	0.394
Jumping Pound	7.043	5.635	Ricinus	2.113	1.324
			Rockyford	0.141	0.141
Kaybob	0.704	0.563	Rosevear	0.873	0.733
Kaybob South (2 plants)	17.327	5.860			
Kessler	0.169	0.141	Savanna Creek	2.113	1.775
Keystone	0.225	0.197	Sedalia	0.141	0.141
Killam	0.282	0.282	Sibbald	0.169	0.141
			Simonette (2 plants)	1.042	0.761
Lacombe	0.141	0.141	Sounding	0.281	0.254
Lac La Biche	0.507	0.507	South Lone Pine Creek	0.986	0.733
Leduc Woodbend	0.986	0.845	Stanmore (2 plants)	0.704	0.535
Leedale	0.113	0.113	Stettler	0.113	0.113
Lone Pine Creek	1.887	1.521	Strachan D-3	7.748	6.029
			Strachan, Ricinus West	11.889	7.241
Marten Hills	3.747	3.663	Sturgeon Lake South	0.648	0.535
Marten Hills South	0.676	0.676	Swalwell (3 plants)	0.902	0.873
McLeod River	0.211	0.169	Swan Hills	0.254	0.113
Medicine River	0.141	0.141	Sylvan Lake (5 plants)	3.719	2.986
Mikwan North	0.423	0.366			
Minnehik-Buck Lake	3.043	2.817	Three Hills	0.085	0.085
Mitsue	0.592	0.423	Three Hills Creek	0.282	0.197
Morinville (2 plants)	1.240	1.127	Turner Valley	1.127	0.958
			Twining Swalwell	0.282	0.254
Nevis, Stettler (2 plants)	6.339	4.959			
Nipisi	0.704	0.394	Virginia Hills	0.338	0.282
North Twining	0.225	0.225	Vulcan	0.704	0.620
Okotoks	0.845	0.366	Waskahigan	0.451	0.366
Olds (2 plants)	2.874	2.198	Waterton	13.185	8.762
Oyen (2 plants)	0.141	0.141	Wayne-Rosedale (3 plants)	2.000	1.747
			West Paddle River	0.507	0.479
Paddle River	2.423	2.057	Whitecourt	1.831	1.719
Parflesh	0.056	0.056	Wildcat Hills	3.155	2.677
Peco (2 plants)	0.338	0.310	Willesden Green (2 plants)	0.479	0.423
Penhold	0.169	1.169	Wilson Creek	0.507	0.423
Phoenix	0.085	0.085	Wimborne (2 plants)	1.803	1.409
Pembina (14 plants)	4.592	3.043	Windfall, Pine Creek	6.057	3.381
Pincher Creek	2.536	1.944	Wintering Hills	0.394	0.366
Plain	1.127	1.127	Wood River	0.141	0.141
Portage	0.563	0.563	Worsley	0.704	0.592
Prevo	0.141	0.113	Zama	0.704	0.535

Table 9 (concl'd)

Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced	Main Gas Field Served	Raw Gas Capacity	Residue Gas Produced
	(million cubic metre/day)			(million cubic metre/day)	
Alberta (concl'd)			**British Columbia**		
Pipeline at Ellerslie[1]	1.972	1.859	Beaver River	6.762	0.845
Pipeline at Empress[2] (2 plants)	92.974	89.650	Boundary Lake (2 plants)	0.282	0.282
Pipeline at Cochrane[3]	25.357	24.652	Clarke Lake	30.991	25.638
			Fort St. John	14.087	12.819
Saskatchewan					
Cantuar	0.704	0.676	**Ontario**		
Coleville, Smiley	1.071	1.042	Becher	0.028	0.028
Hatton	0.225	0.197	Corunna (2 plants)	0.140	0.141
Dollard	0.056	0.056	Port Alma	0.451	0.451
Milton	0.113	0.113			
Smiley	0.056	0.028			
Steelman	1.071	0.845			
Totnes	0.197	0.197	**Northwest Territories**		
West Gull Lake	0.423	0.394	Pointed Mountain	5.325	2.817

Source: *Natural Gas Processing Plants in Canada* (operators List 7) January 1977, Department of Energy, Mines and Resources, Ottawa.
[1]Plant reprocesses gas owned by Northwestern Utilities Limited. [2]Plant reprocesses gas owned by TransCanada PipeLines Limited [3]Plant reprocesses gas owned by exporting companies.

In Quebec, the Quebec crown corporation, Quebec Petroleum Operations Company (SOQUIP) announced the results of a drilling program in the St. Lawrence Lowlands about 48 km southwest of Quebec City. Three wells in the St. Flavien area are capable of producing 113 280 m^3 (4 MMcf/d) of gas from a horizon at the 5 000-foot level. No reserve figures are given for the field but it is believed to cover about 25 894 400 m^2 (6 400 acres). Two wells in the Villeroy region produced 28 000 m^3 (1 MMcf/d) of gas from fractured shales in the Utica and Lorraine groups. The reservoir characteristics of both fields were relatively poor. At the present time there are no markets within economical reach for gas from these fields.

In Ontario during the past year 144 exploratory and development wells were drilled, compared with 138 exploratory wells drilled in 1975. Of these, 67 were classed as gas discoveries. As in previous years much of the exploratory activity was confined to the Silurian pinnacle reef trend along the east flank of the Michigan Basin in Lambton County. The most notable discovery was made by Husky Oil Ltd. in Enniskellin Township. The discovery, with a gross pay zone of 198 feet, was a follow-up to an earlier oil and gas discovery and the successful completion is the latest in Husky's Ontario exploration program that commenced in 1973.

Reserves

At the end of 1976 the Canadian Petroleum Association (CPA) estimated Canada's proven reserves of marketable gas at 1 642 035 million m^3 (58.28 tcf), 36 830 million m^3 (1.3 tcf) more than in 1975. Using the 1976 level of production of 75 535 million m^3 (2.66 tcf), the life index (reserves to production level) increased to 21.85 years in 1976 compared with 21.5 years in 1975. Gross additions to reserves amounted to 109 299 million m^3 (3.86 tcf), including 101 668 million m^3 (3.59 tcf) attributed to extensions to existing fields, 18 124 million m^3 (.64 tcf) to new discoveries, and a downward revision of 10 195 million m^3 (.36 tcf) to previously-estimated field reserves. Almost all of the increase was accounted for by increases in reserves in Alberta and the Territories. Gross additions of marketable gas in Alberta amounted to 69 467 million m^3 (2.45 tcf) and most of this was due to extensions of existing fields. Gas reserves in the Territories, which include the Mackenzie Delta but not the Arctic islands, increased by 34 190 million m^3 (1.20 tcf), primarily by revisions of previous estimates. In placing Mackenzie Delta gas in the proven category, the CPA assumed that Delta gas would eventually be brought to market via the same pipeline system as Prudhoe Bay gas from Alaska, therefore no threshold volumes were required before categorizing them as proven. This is not the case for Arctic islands gas where a minimum reserve base is required before this gas can be considered to be within economic reach. Therefore gas reserves that have been found in the Arctic islands are classified as probable rather than proven. The CPA credited the Arctic islands with 269 040 million m^3 (9.5 tcf) of probable reserves at the end of 1976.

Alberta, with 1 292 076 million m^3 (45.6 tcf) of marketable gas reserves, accounted for 78 per cent of Canadian reserves at the end of 1976, British Columbia 11.4 per cent and the Territories 8 per cent.

Natural gas processing

Gas processing capacity increased in 1976 because of the addition of a record number of new plants and some expansion to existing facilities. Almost all of the new facilities constructed were in the small-plant category. As natural gas prices have increased there have been a multiplicity of new field discoveries and older fields previously considered to be uneconomic are now being produced. The largest expansion of existing gas plant capacity was completed by Canada-Cities Service, Ltd. at its Paddle River plant. Raw gas intake capacity was increased from .85 million m^3 a day to 2.43 million m^3 a day (30 MMcf/d to 86 MMcf/d). At the same time, residue sales gas output was raised to 2.06 million m^3 a day (73 MMcf/d), with a substantial increase in the production of a mixed propane-butane stream. Other major expansions included Pacific Petroleums, Ltd.'s upgrading of their Kaybob gas processing plant by the addition of another section on the same site. New capacity will include a raw gas intake of .70 million m^3 a day (25 MMcf/d). Output includes

Table 10. Kilometres of gas pipelines in Canada, 1972-76p

	1972	1973	1974	1975	1976p
Gathering					
New Brunswick	9.7	9.7	9.7	9.7	20.9
Quebec	1.6	1.6	1.6	1.6	1.6
Ontario	1 828.2	2 026.1	1 825.0	1 839.5	1 992.4
Saskatchewan	1 483.8	1 549.8	1 208.6	1 643.1	2 290.1
Alberta	6 762.5	7 740.9	9 025.2	10 050.4	12 849.0
British Columbia	1 591.6	1 649.6	1 736.5	1 907.1	2 069.6
Northwest Territories and Yukon	—	—	54.7	54.7	54.7
Total	11 677.4	12 977.7	13 861.3	15 506.1	19 278.3
Transmission					
New Brunswick	20.9	20.9	20.9	20.9	20.9
Quebec	238.2	238.2	238.2	238.2	238.2
Ontario	7 000.6	8 410.4	9 239.2	9 224.8	9 387.3
Manitoba	2 558.9	2 640.9	2 645.8	2 743.9	2 743.9
Saskatchewan	9 649.6	10 241.9	10 513.8	10 581.4	10 615.2
Alberta	12 578.6	13 005.1	12 853.8	13 930.5	15 596.2
British Columbia	4 774.9	4 879.5	4 894.0	5 042.1	5 087.1
Total	36 821.7	39 436.9	40 405.7	41 781.8	43 688.8
Distribution					
New Brunswick	51.5	51.5	51.5	51.5	146.5
Quebec	2 724.6	2 772.9	2 764.9	2 975.7	2 890.4
Ontario	26 718.3	26 385.2	27 395.9	28 033.2	28 715.5
Manitoba	2 748.8	2 850.1	2 937.1	2 655.4	2 739.1
Saskatchewan	4 099.0	4 362.9	4 615.6	4 789.4	4 966.4
Alberta	13 932.1	14 917.0	16 523.1	18 851.9	21 553.9
British Columbia	9 437.2	9 957.0	8 946.3	9 285.9	9 397.0
Total	59 711.5	61 296.6	63 234.4	66 643.0	70 408.8
Total Canada	108 210.6	113 711.2	117 501.4	123 930.9	133 375.9

Source: Statistics Canada.
— Nil; pPreliminary.

.58 million m³ a day (20.5 MMcf/d) of residue gas, a mixed propane stream of 257 m³ a day (1620 b/d), 144 m³ a day (912 b/d) of butane and 74 m³ a day (468 b/d) of condensate.

In new plant construction, two medium-sized plants were placed on stream this year. One of these was Dome Petroleum Limited's West Paddle River plant, south of the Paddle River plant of the Paddle River field, which started up in mid-1976 and at full capacity will process .50 million m³ a day (17.8 MMcf/d) of raw gas to produce 52 m³ a day (325 b/d) of stabilized condensate, 57 m³ a day (360 b/d) of liquified petroleum gas (LPG) mix and .48 million m³ a day (17 MMcf/d) of residue gas. The other intermediate-sized plant constructed in 1976 was Sun Oil Company Limited's Rosevear plant. It was completed in mid-1976 and is now processing .90 million m³ (32 MMcf/d) of intake gas to produce .74 million cubic metres a day (26 MMcf/d) of dry residue gas, 35.5 cubic metres a day (230 b/d) of pentanes plus and 92 tonnes a day of sulphur.

Construction of new plants was confined to small gas-processing units in 1976 and there were several of these. Among the most important was Bumper Development Corporation Ltd's Carbon field plant which has a raw gas intake of .20 million m³ a day (7 MMcf/d) to produce 5 m³ a day of pentanes plus and .20 million m³ a day (7 MMcf/d) of residue gas. In the Bashaw field, Home Oil Company Limited's .34 million m³ a day (12 MMcf/d) compression-adsorption plant came on stream this year. This plant also produces 8 m³ a day (50 b/d) of pentanes plus and .339 million m³ a day (12 MMcf/d) of residue gas. In the Davey field, The Polumbus Corporation's dehydration-compression plant commenced operation in late-1976 and recovers 2.4 m³ a day (15 b/d) of propane mix and .23 million m³ a day (8 MMcf/d) of residue gas from a raw gas intake of .23 million m³ a day (8 MMcf/d). A new gas-processing plant came on stream in the Maple Glen field. Wainoco Oil Ltd's compression-refrigeration plant will process .31 million m³ a day (11 MMcf/d) of raw gas intake to produce .28 million m³ (10 MMcf/d) of residue gas and 3 m³ a day (18 b/d) of pentanes plus.

Construction under way includes Imperial Oil Limited's plant in the Edson area which is due to come on stream in mid-1977. The plant will serve the Niton oil and gas fields and is a refrigeration type which will produce residue gas and a mixed-liquid product. Its raw gas capacity is .85 million m³ a day (30 MMcf/d) to produce .78 million m³ a day (28.5 MMcf/d) of residue gas plus 95 m³ a day (600 b/d) of propane mix. Another large project currently under construction and expected to come on stream in 1977 is Shell Canada Limited's expansion of its Burnt Timber processing plant. Here, raw gas intake will be doubled to 3.9 million m³ a day (140 MMcf/d) to produce 3.2 million m³ a day (114 MMcf/d) of residue gas, 91 m³ a day (574 b/d) of condensate and 339 tonnes per day of sulphur.

Future major expansion of the gas processing industry will likely take place in the Alberta foothills and the frontier regions when reserves can be developed economically. In the foothills, two recent major gas strikes are currently being delineated by Shell, and they have resulted in firm proposals for the construction of two large gas plants — one at Limestone Mountain and the other at Willson Creek. Tentative completion dates of

Table 11. Canada sales of natural gas by province, 1976ᵖ

	000 cubic metres	($000)	Average $/000 cubic metres	No. of Customers Dec. 31/76
New Brunswick	2 663	224	84.12	730
Quebec	2 277 728	157 650	69.21	187 430
Ontario	19 178 373	1 141 082	59.50	1 058 575
Manitoba	1 725 902	91 140	52.81	158 513
Saskatchewan	2 671 995	103 038	38.56	194 077
Alberta	9 074 087	232 586	25.63	444 957
British Columbia	3 906 777	169 823	43.47	354 542
Total Canada	38 834 919[1]	1 895 543	48.81	2 399 824
Previous totals				
1972	32 457 954	740 383	22.81	2 039 095
1973	34 827 379	797 856	22.91	2 131 090
1974	37 231 875	980 395	26.33	2 219 549
1975	37 526 031	1 307 287	34.84	2 300 039

Source: Statistics Canada.
[1]Provincial totals do not add to Canada total because of rounding by Statistics Canada.
ᵖ Preliminary.

late-1979 hinge on the results of future development drilling. Elsewhere, Shell has embarked on a major modification of its Waterton plant designed specifically to increase the recovery of propane and butane from the raw gas intake.

In the Mackenzie Delta where several major gas discoveries have been made, a proposal to build two gas-processing plants of 42 million m^3 a day (1.5 Bcf/d) capacity has been submitted to the federal government by a joint development group comprised of Gulf Oil Canada Limited, Imperial Oil Limited and Shell Canada Limited. The $1.1 billion project would involve the construction of a 42-million m^3 a day (1 Bcf/d) gas plant to be located at the Taglu field to process gas from this field and the Niglintgak field, 16 km farther west. The second plant will be constructed at the Parsons Lake field, about 51 km southwest of the Taglu field and will have a capacity of 14 million m^3 a day (500 MMcf/d).

Transportation

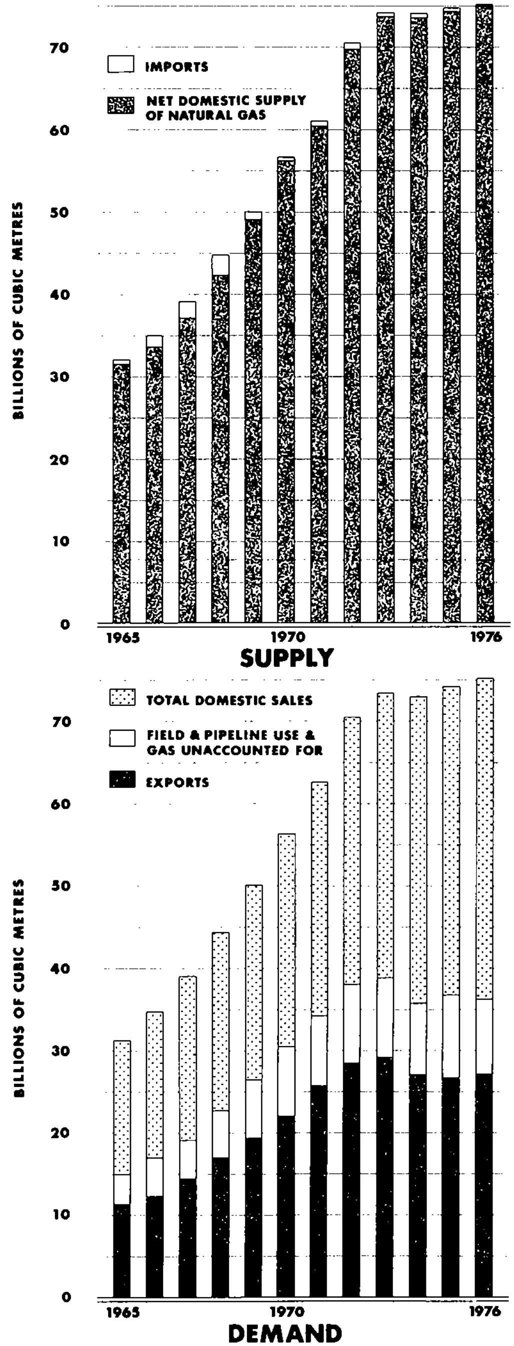
Gas pipeline constructed in 1976 showed a marked increase over 1975 as 9 446 km of pipelines were added to gas transmission, distributing and gathering systems, compared with 6 430 km in 1975. By the end of 1976 total cumulative gas pipeline mileage was 133 376 metres.

Gas transmission and distribution lines accounted for the bulk of the increase as construction in these categories reached record proportions. Much of the gathering system construction was confined to Alberta where a record number of new gas fields were brought into production in 1976. Gas gathering lines increased by 3 772 km and distributing pipelines systems were enlarged by 3 766 km. The largest project in the gathering-line category was the completion of 362 km of gathering system for the Alberta Energy Company in the British Block of southeastern Alberta where over 56 650 m^3 (2 tcf) of gas reserves are known to exist. Part of the increase in distribution pipeline occurred east of Alberta as gas utility companies expanded their commercial services late in the year. Nevertheless, the bulk of the expansion occurred in Alberta as that province commenced its rural gasification program.

Gas transmission line construction in 1976 was almost entirely confined to small-diameter projects as demand for gas in markets east of Alberta continued to lag. The largest gas pipeline construction project in 1976 was carried out by TransCanada PipeLines Limited on its main line between Toronto and Montreal with the completion of 77 km of 61 cm line and in addition, 27 km of 40 cm lateral to Ottawa.

Most of the smaller-diameter projects were carried out in Alberta as The Alberta Gas Trunk Line Company Limited was in the midst of a major expansion program. The most notworthy project in this program was located in north-central Alberta where a total of 115 km in four new laterals was installed. The laterals varied in diameter from 250 mm to 200 mm, were all

SUPPLY – DEMAND of NATURAL GAS in CANADA



constructed in the Athabasca region, and will connect several new gas fields in that area to market centres.

The series of hearings which were commenced in October 1975 by the National Energy Board (NEB) to determine the feasibility of building a natural gas pipeline from the mainland Arctic regions, continued in 1976. Originally, two competing applications to construct the pipeline were being reviewed at the same time — those of Canadian Arctic Gas Study Limited (CAGSL) and Foothills Pipe Lines Ltd. CAGSL proposes to build a 1.22-metre pipeline that will carry natural gas from Alaska and the MacKenzie delta to markets in both Canada and the United States. The 3 860 km pipeline will cost an estimated $8 billion to $10 billion. Foothills proposes a 319 km, 1.1 metre line that would join up with existing distribution systems

Table 12. Canada, supply and demand of natural gas

	1975		1976p	
	(Millions cubic metres)	(Millions cubic metres)	(Millions cubic metres)	(Millions cubic metres)
Supply				
Gross new production		99 321		99 383
Field waste and flared		−1 418		−1 318
Reinjected		−10 383		−10 519
Net withdrawals		87 520		87 546
Processing shrinkage		−12 466		−12 011
Net new supply		75 054		75 535
Removed from storage	3 175		3 762	
Placed in storage	−4 726		−4 293	
Net storage		−1 551		−531
Total net domestic supply		73 503		75 004
Imports		289		115
Total supply		73 792		75 119
Demand				
Exports		26 822		27 013
Domestic sales				
Residential	8 476		8 862	
Industrial	20 951		21 619	
Commercial	8 099		8 354	
Total		37 526		38 835
Field and pipeline use				
In production	6 242		6 299	
Pipeline	3 477		2 763	
Other	605		906	
Adjustment metering differences	−488		−389	
Line pack changes	63		115	
Total field and pipeline use		9 899		9 694
Gas unaccounted for		−455		−423
Total demand		73 792		75 119
Total domestic demand		46 970		48 106
Average daily domestic demand		129		131

Sources: Statistics Canada and provincial government reports.
p Preliminary.

in Alberta and British Columbia and bring only Canadian gas to Canadian markets. Cost of this line has escalated to $3 billion, with an additional $2 billion required to expand existing southern systems.

On August 31, 1976 a consortium headed by Foothills Pipe Lines (Yukon) Ltd. filed an application with the NEB for permission to construct a 823-km pipeline of 1 metre diameter in the Yukon Territory as its contribution to the proposed Alcan project to transport Alaska natural gas to United States markets. The system would follow the trans-Alaska crude oil pipeline, currently under construction, to Fairbanks, Alaska and then parallel the Alaska highway to northeast British Columbia, where it would either connect with the Alberta Gas Trunk Line and Westcoast Transmission systems or proceed directly to southern Alberta. Here it would split so as to serve markets in the United States' northwest and mid-continent regions. The NEB decided to incorporate the Alcan proposal in the hearing currently under way on the northern pipeline proposals of CAGSL and Foothills. The Board believed that a consolidated hearing for the three projects would result in a faster decision than having a separate hearing for the Alcan project. A decision as to which (if any) of these three proposals is the most acceptable is anticipated late in 1977.

The Polar Gas Project, which proposes construction of a 1.2-metre, island-hopping pipeline to deliver natural gas to southern markets from the Arctic islands came closer to realization this year with the discovery of substantial new gas reserves in that area. The problem is not so much one of constructing the line, although it would be difficult, but rather establishing in the islands gas reserves large enough to sustain the economic operation of the line long enough to justify the capital expenditures required for its construction. Current industry estimates place the minimum or "threshold" reserves required a 707 750 million m^3 (25 tcf), of which unofficial estimates indicate about half has already been found.

In the event that sufficient reserves are not found to justify the cost of building such an expensive pipeline as Polar Gas envisages, other transportation modes such as ice-strengthened liquefied natural gas (LNG) tankers will likely be considered as an alternative. Although this is a relatively expensive method of transporting natural gas, it involves a smaller initial capital cost than pipelines and a more rapid rate of return on investment.

Markets and trade

Total natural gas sales increased by 1 500 million m^3 (52 929 MMcf) to an estimated 65 848 million m^3 (2 324 480 MMcf) in 1976. The nominal growth rate was distributed between domestic and export markets. Export sales increased by 520 thousand m^3 a day (18.3 MMcf/d) while demand in the domestic market rose by 3.57 million m^3 a day (126 MMcf/d).

Residential users led the way in consumption growth rate with a gain of 4.6 per cent to 24.2 million m^3 a day (855 MMcf/d) and this can largely be attributed to the unseasonally cold weather experienced during the latter part of 1976. Sales in the industrial sector rose by about 3 per cent to 59.0 million m^3 a day (2085 MMcf/d) while sales to commercial consumers increased by 3 per cent to 22.8 million m^3 a day (806 MMcf/d). Total revenue from all sales of gas in Canada and from exports amounted to $3 512 million in 1976 and of this amount domestic sales accounted for $1 895 million — 44 per cent more than 1975 sales of $1 307 million. The value of export sales rose to $1 616 million, 48 per cent higher than in 1975.

Ontario and Alberta accounted for the bulk of the increase in Canadian consumption in 1976 and Ontario remained the largest user, consuming 49 per cent of all gas used in Canada. Alberta is the second-largest consuming province and accounted for 23 per cent of all gas marketed in Canada in 1976. Sales in British Columbia declined, as did sales in Quebec. Sales in New Brunswick, Manitoba and Saskatchewan remained at the same level as in the previous year. The remaining three provinces; Nova Scotia, Prince Edward Island and Newfoundland, do not have natural gas service.

Exports to the United States increased by less than 1 per cent to 73.77 million m^3 a day (2 605 MMcf/d). Currently, authorized export volumes to the United States average about 78.2 million m^3 a day (2 762 MMcf/d) including 54.7 million m^3 (1 934 MMcf/d) scheduled for United States westcoast markets and about 23.4 million cubic metres (828 MMcf/d) for midwest and eastern customers. However, since 1974, Westcoast Transmission Company Limited has been unable to meet its contractual requirements with United States customers, largely due to a chronic and deteriorating supply problem in some large British Columbia gas fields. In regard to future exports, and within the framework of the recommendation of the report *Canadian Natural Gas — Supply and Requirements* prepared by the NEB in 1976, the federal government announced its intention to cut back natural gas exports because of the shortages of gas supply predicted to begin in 1976. Since these shortages did not develop, there was no immediate plan to substantially reduce natural gas exports to the United States. Nevertheless, the federal government retains the right to curtail exports to the United States if a deteriorating reserve position so dictates. However, it would appear that our current supply situation has improved to the extent that curtailment of exports to the United States is not likely in the near future, if at all. At the present time export volumes amount to about 35 per cent of total Canadian gas production and no applications for increases in long-term exports have been granted since 1970. However, it is possible that additional exports could be approved on a short-term, interruptible basis in the event indigenous gas reserves showed gains in excess of the growth in domestic demand.

In respect to future growth in consumption in domestic markets, the Alberta government approved five separate recommendations of the AERCB for removal of natural gas from the province. The approvals represent essentially the first additional Alberta natural gas exported from the province since 1971. The bulk of the gas will go to TransCanada PipeLines Limited and involves an additional volume of 39 648 million m^3 (1.4 tcf). The gas will be for use in eastern Canada, primarily Ontario, and should be adequate to meet demand growth in the ex-Alberta domestic market for at least the next two or three years.

The question of price for oil and natural gas continued to occupy a major position in industry developments in 1976. Although no general agreement could be reached at the First Ministers' Conference held on May 6, 1976 to determine new price schedules for oil and gas; later, after consultation with the producing provinces and under the authority of the Petroleum Administration Act, new prices for oil and gas were set. In respect to gas, the increases were introduced in two stages: domestic natural gas prices which had been set at $1.25 per 28.32 m^3 (1 Mcf) at Toronto city gate were increased to $1.40 1/2 per 28.32 m^3 (1 Mcf) on July 1, 1976, and to $1.50 1/2 on January 1, 1977.

The federal government also raised the price of exported natural gas in two stages in 1976, the second stage to become effective in 1977. On September 10, 1976, the price was increased from $1.60 to $1.80 per 28.32 m^3 (1 Mcf) then to $1.94 per 28.32 m^3 (1 Mcf) on January 1, 1977. The increase follows the federal policy of receiving full market value for this commodity. Canadian producers will receive a well-head price for gas of $1.12 per 28.32 (1 Mcf) on January 1, 1977, up from the present 91 cents per 28.32 cubic metres (1 Mcf).

In May 1976 the federal government announced the elements of a federal Petroleum and Natural Gas Act which is expected to be placed before Parliament sometime in 1977. The Act will provide for a new regulatory system to govern the manner in which oil and gas rights are made available for development in Canada's territories and offshore regions. This new legislation is designed to promote the early assessment of Canada's frontier oil and gas resources through incentives to explore, and disincentives on land that remains idle. Also included are mechanisms that require a certain pace in territorial exploration permit evaluation. This is in accordance with the goal of self-reliance and the elements of the national energy strategy announced in late April 1976. Given this desirability, there is an essential "need to know" associated with the early delineation of Canada's resource base. The Act also has elements to stimulate exploration which include fiscal and land-holding incentives, together with complementary provisions for greater government control over the timing, direction, rate and level of exploration, development and production activities. In addition, the legislation will permit Canadian firms, including Petro-Canada, to benefit more fully from the development of the resource base.

Composition and uses of natural gas

Marketed natural gas consists chiefly of methane (CH_4) but small amounts of other combustible hydrocarbons such as ethane (C_2H_6) and propane (C_3H_8) may also be present. Methane is nonpoisonous and odourless, but a characteristic odour is usually introduced into marketed natural gas as a safety measure. The heat value of natural gas averages about 1 000 British thermal units per cubic foot of gas.

Raw natural gas, as it exists in nature, may vary widely in composition. Besides the usually-predominant methane, varying proportions of ethane, propane, butane and pentanes plus may be present. Water vapour is a normal constituent. Hydrogen sulphide, although not present in some Canadian natural gas, is commonly so abundant as to be an important source of sulphur. Other nonhydrocarbon gases which may be present, usually in small amounts, are carbon dioxide, nitrogen and helium.

The largest use of natural gas is as a fuel. Residentially, gas is extensively used in space and water heating and cooking, but is becoming common as a fuel for air conditioners, incinerators, dishwashers and laundry equipment. In industrial areas, natural gas has been a boon to such industries as automobile plants, iron and steel complexes, metal working firms, glass factories and food processors. For example, in steelworking, the clean, easily-controlled flame of natural gas enables the desired temperatures to be attained in rolling, shaping, drawing and tempering steel. Natural gas is also a major source of feedstock for the chemical industry. Ethane, seldom removed from natural gas at the field processing plant in the past, has become a valuable petrochemical feedstock, and ethane recovery on a large scale is now taking place. Natural gas supplies basic raw material for ammonia, plastics, synthetic rubber, insecticides, detergents, dyes and synthetic fibres such as nylon, orlon and terylene. Important future uses may include fuel-cells and power-generator systems driven by gas turbines.

Canada continues to be one of the world's largest producers of elemental sulphur, a byproduct recovered in the processing of sour (hydrogen sulphide) gas from fields in western Canada.

Nepheline Syenite and Feldspar

G.H.K. PEARSE

Nepheline syenite is a white to whitish-grey, medium-grained igneous rock resembling granite in texture. It consists of nepheline, potash and soda feldspar, and accessory mafic minerals such as biotite, hornblende and magnetite. Although nepheline syenite is a rock type known to occur in many parts of Canada, its industrial application is limited to those deposits from which iron-bearing accessory minerals can readily be removed; its major uses are in the glass and ceramics industries.

The use of nepheline syenite as a raw material for glass, ceramic and the filler industries was first developed in Canada, which was the world's sole producer for many years. Canada's only competitor in the field, Norway, began nepheline syenite mining and milling in 1961. Although the U.S.S.R. began mining nepheline syenite on the Kola Peninsula during the 1930s, the deposit was worked for its phosphate content. Byproduct nepheline from the Kola deposit became an important source of aluminum and is still being used for this purpose. Nepheline syenite is also quarried in the United States for use as aggregate, railway ballast, jettystone and roofing granules.

Canada's nepheline syenite industry began in 1932 with the staking of five claims on Blue Mountain, 25 miles northeast of Peterborough. A long period of persistent efforts in technical and market research and in development was necessary before this unique industry became established. Today there are two mills in operation on Blue Mountain processing rock from several quarries.

Over the years nepheline syenite has become preferred to feldspar as a source of essential alumina and the alkalis in glass manufacture. Its use results in more rapid melting of the batch at lower temperatures than with feldspar, thus reducing fuel consumption, lengthening the life of furnace refractories and improving the yield and quality.

Industrial uses for nepheline syenite, other than for glass manufacture, include ceramic glazes, enamels, and fillers in paints, papers, plastics and foam rubber.

Feldspar is the name of a group of minerals consisting of aluminum silicates of potassium, sodium and calcium. Feldspar is used in glassmaking as a source of alumina and the alkalis, in ceramic bodies and glazes, in cleaning compounds as a moderate abrasive and as a flux coating on welding rods. High-calcium feldspars, such as labradorite, and feldspar-rich rocks such as anorthosite, find limited use as building stones and for other decorative purposes. Dental spar, which is used in the manufacture of artificial teeth, is a pure white potash feldspar free of iron and mica.

Feldspar occurs in many rock types, but commercially viable deposits are mostly restricted to coarse-grained pegmatites from which the mineral is concentrated by flotation or, less commonly, by handcobbing. It is then ground to the desired size. Nearly all of the feldspar produced in Canada has come from pegmatites in the Precambrian rocks of southern Ontario and southwestern Quebec.

Canadian production and developments

Nepheline syenite production comes from two operations on Blue Mountain in Methuen Township, Peterborough County, Ontario. The deposit is pearshaped, approximately five miles long, and up to one and one-half miles wide. The iron content of the rock is distributed quite uniformly, but selective quarrying, blending of quarry material, and careful pit development are necessary to ensure a mill product capable of meeting consumer specifications. In general, the nepheline syenite zone is underlain by syenites and overlain by steeply dipping biotite schists. Nepheline syenite reserves are sufficient to satisfy demand for the foreseeable future.

Indusmin Limited, a subsidiary of Falconbridge Nickel Mines Limited, is the larger producer. Output in 1976 was 346 000 tonnes*, an increase of 24 per cent over that of 1975. The company's operation in Nephton, Ontario, was originally worked by its predecessor, American Nepheline Limited. Ore is cur-

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, nepheline syenite production, exports and consumption, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)	468 427	8 869 497	541 000	10 828 000
Exports				
United States	345 064	6 625 000	404 129	7 920 000
Australia	1 198	75 000	2 488	138 000
United Kingdom	4 374	75 000	4 789	86 000
Italy	505	22 000	990	38 000
France	809	33 000	658	22 000
Spain	362	15 000	293	8 000
Greece	201	7 000	233	8 000
Dominican Republic	279	19 000	227	8 000
Other countries	3 294	240 000	1 001	40 000
Total	356 086	7 111 000	414 808	8 268 000

	1974	1975p
	(tonnes)	
Consumption[1] (available data)		
Glass and glass fibre	65 278	62 539
Whiteware	15 301	17 281
Mineral wool	23 941r	18 117
Paints	3 202	2 529
Porcelain enamel	233	322
Others[2]	2 926	2 986
Total	110 881r	103 774

Source: Statistics Canada.
[1]Total and breakdown by Mineral Development Sector. [2]Includes miscellaneous chemicals, gypsum products, rubber products, paper and paper products, plastics and other minor uses.
pPreliminary; rRevised.

rently being mined from five open pits. Rock is blasted from the pit face and loaded by electrically powered shovels into trucks for haulage to an adjacent mill at Nephton. The mill, which was built in 1956 and subsequently expanded to 1 000-tonne-a-day capacity, operates on three shifts a day, seven days a week, and produces several grades of nepheline syenite to meet a wide variety of markets. The various grades produced are based on combinations of differing mesh sizes and iron content. Iron-bearing minerals are almost totally removed by electromagnetic methods. Finished products are transported by rail through Havelock, Ontario, 18 miles south of the mill, to domestic and exports markets. The United States accounts for as much as 75 per cent of Indusmin's sales.

A major expansion of the secondary milling circuit, postponed in 1975, was completed in 1976 to meet strong demand for finely ground filler and extender-grade product.

IMC Chemical Group (Canada) Ltd. (formerly Sobin Chemicals (Canada) Ltd.), a wholly owned subsidiary of International Minerals & Chemical Corporation, operates quarries and a plant about four miles east of Indusmin's operation.

The mill was constructed in 1956 on a part of the deposit originally staked in 1932 by the Canadian Flint and Spar Company, Limited. Present capacity is 800 tonnes a day. The mill operates three shifts daily, seven days a week, and produces a variety of products, based on mesh sizes and iron content, suitable for many industrial uses. Rock is mined from an open pit adjacent to the mill and a certain degree of blending from various parts of the pit is required to ensure an acceptable mill feed. Ore reserves are sufficient for many years.

IMC's production is railed to Havelock, Ontario for distribution to various markets; up to 90 per cent being exported to the United States. The company produces three grades of nepheline syenite for glass, enamel, fibre and other applications.

In 1976, total nepheline syenite shipments amounted to 541 000 short tons valued at $10 828 000, a tonnage increase of 16 per cent from 1975 and a value increase of 22 per cent, reflecting both price increases during the year and increased sales of high-value filler and pigment-extender grades. However, this production remains below the 1974 peak of 551 000 tonnes.

During the 1950s and 1960s, shipments increased at the rate of 17 per cent a year and 8 per cent a year, respectively. This dramatic growth was due largely to recognition by glassmakers of the superior properties, consistent quality, long-term reliable supply, and low cost of nepheline syenite, compared with feldspar. Deceleration in growth over the years has occurred as markets formerly held by feldspar are nearing the saturation point. During the last five years growth has been stagnant because of several factors, including strikes in the consuming industries, shortages of rail cars, and, finally, decreasing demand.

As a result of substitution by nepheline syenite, output of feldspar declined steadily from 55 000 tons in 1947 to 10 000 tons in 1961, a level that persisted throughout the 1960s and continues to be Canada's tonnage requirement. This competition led to closure of Canada's last feldspar producer, International Minerals & Chemical Corporation (Canada) Limited's Buckingham, Quebec mine in 1972. However, since closure, a shortage of potash feldspar, for which there is, as yet, no acceptable substitute in the manufacture of high-voltage electrical porcelain insulators, has developed in both the United States and Canada. Several local producers of high-value dental spar had delivered small tonnages to the mill at Buckingham until the recent closure. In 1974, one operation shipped several tons to Sweden and an enquiry for a possible several hundred tons, following assessment of a trial shipment, was received during 1975 from a North American manufacturer.

Tantalum Mining Corporation of Canada Limited mines tantalum and lithium from a pegmatite at Bernie Lake, Manitoba containing abundant feldspar. This company could recover a clean quartz-feldspar product, should market demand warrant.

Table 2. Canada, nepheline syenite production and exports, 1965, 1970, 1974-76

	Production[1]	Exports
	(tonnes)	
1965	308 426	224 256
1970	454 110	351 940
1974	559 986	454 699[r]
1975	468 427	356 086[r]
1976[p]	541 000	414 808

Source: Statistics Canada.
[1]Producers' shipments.
[p]Preliminary; [r]Revised.

Other domestic occurrences

Nepheline syenite is known to occur in many localities in Canada but, to date, only the Blue Mountain deposit has proven amenable to economic mining and milling to produce material suitable for the glass and ceramic markets. Other occurrences are either too high in iron content or too variable in chemical composition to allow large-scale, open-pit development.

An extensive body of nepheline syenite outcrops in the Bancroft area of Ontario. Small tonnages of this material were mined from 1937 to 1942, but the product proved unacceptable because of considerable variation in the nepheline content and an overabundance of iron-bearing accessory minerals. Tontine Mining Limited (now Coldstream Mines Limited) discontinued exploration work in 1971 on a large nepheline syenite intrusive located near Port Coldwell, Ontario, after obtaining discouraging results from petrologic and metallurgical studies.

Nepheline syenite occurs in several localities in southern British Columbia, notably in the Ice River area, near Field, and in the Big Bend area on the Columbia River.

Table 3. Canada, feldspar consumption, 1974-75

	1974	1975[p]
	(tonnes)	
Consumption[1] (available data)		
Whiteware	6 491	5 386
Porcelain enamel	262	214
Others[2]	94	30
Total	6 847	5 630

Source: Statistics Canada.
[1]Breakdown by Mineral Development Sector. [2] Includes artificial abrasives, electrical apparatus, glass and other minor uses.
[p]Preliminary; — Nil.

Nepheline is a common mineral constituent in the alkaline complexes of northern Ontario and southern Quebec, but none of these deposits are, as yet, of economic significance.

Feldspar is the major mineral constituent of pegmatite dykes which are widely distributed in Canada. Any large deposit near potential markets warrants investigation.

Markets

In 1976, 77 per cent of Canada's nepheline syenite output was exported. Sales to the United States increased 17 per cent above 1975 to reach 404 129 tonnes; 97 per cent of total exports.

Canadian offshore sales were 11 000 tonnes in 1976, little changed from the previous year, but about half that of 1974.

Domestic shipments increased 12.5 per cent to an estimated 126 000 tonnes in 1976, or 23 per cent of producers' shipments. Of this, about 60 per cent was used in glass and glass fibre manufacture.

In the glass industry, 15 to 20 per cent by weight of the glass batch is nepheline syenite. Material with a size range of minus 30 mesh to plus 200 mesh and with an iron content of less than 0.1 per cent is required in the production of flintglass. An iron content as high as 0.6 per cent, expressed as Fe_2O_3, is allowable for the manufacture of coloured glass. A typical chemical analysis for high-quality nepheline syenite produced in Canada for glass manufacture is:

Silica SiO_2	—	60.00
Alumina Al_2O_3	—	23.60
Iron Fe_2O_3	—	0.07
Lime CaO	—	0.30
Magnesia MgO	—	0.10
Potash K_2O	—	5.30
Soda Na_2O	—	10.20
Loss-on-ignition	—	0.50

A growing market is developing for finely ground material in the whiteware industry. The finer grades used for ceramic applications are produced by reducing the basic minus 30 mesh material in pebble mills. In ceramics, nepheline syenite is used as both a body and a glaze ingredient. High-purity material in the minus 200 / plus 375 mesh size and with an iron content of 0.07 per cent Fe_2O_3, or less, is most frequently used. Products utilizing this material include bathroom fixtures, vitreous enamels for appliances, china, ovenware, electrical procelain and ceramic artwares.

Table 4. Canada, feldspar production and consumption, 1965, 1970, 1974-76

	Production[1]	Consumption
	(tonnes)	
1965	9 892	7 564
1970	9 667	6 840
1974	—	6 847
1975	—	5 630
1976[p]	—	

Source: Statistics Canada.
[1]Producers shipments. 1966 exports, 3 102 tonnes; the last year for which export statistics were available.
[p]Preliminary; — Nil; . . Not available.

Very finely ground material is being used increasingly as a filler in plastics, foam rubber and paints. Fine-grinding down to 10 microns is accomplished in pebble- and fluid-energy mills. The very fine grain size, high reflectance and low oil absorption are important physical characteristics which make nepheline syenite an excellent filler material in the above products, vinyl, and floor and wall tile.

A low-grade nepheline syenite is sold in bulk for use in the manufacture of fibre glass and for glazing on brick and tile. Some material with high iron content is used in the manufacture of mineral wool, and as an aggregate.

Substitution of alternative materials for feldspar in ceramic manufacture has been less severe than in the manufacture of glass. The principal reason is that raw materials costs are low in the ceramic industry in relation to total manufacturing costs, and manufacturers adopt a new raw material only after cautious trial use and extensive evaluation. Further, while the higher alumina content of nepheline syenite has been a decisive factor in the replacement of feldspar in glass manufacture, a high alumina content is less critical in ceramic manufacture. In ceramics, potash feldspar is used to bind the ceramic mix into what the industry terms a "body", and in the manufacture of electric porcelain for high voltage purposes, this mineral is essential. The domestic market for feldspar appears to be firm at around 9 000 tonnes a year.

World reveiw

The Norsk Nefelin Division of Christiania Spiegerwerk is western Europe's only producer of nepheline syenite. Operations at the plant, near Hammerfest in northern Norway, began in 1961 and increased steadily from an output of 23 000 tonnes in 1963 to 200 000 tonnes in 1973. The latest expansion, completed in 1973, raised capacity from 175 000 to 225 000 tonnes a year. The lenticular deposit is over one mile long, and at least 750 feet deep. Unlike Canadian producers, Norsk Nefelin mines underground, drilling and blasting by conventional techniques. Nepheline syenite is supplied to the glass, ceramic and enamel industries in two main grades; glass grade is about 28 Tyler mesh, and ceramic grade is 200 Tyler mesh. The finer-mesh ceramic-grade material is usually shipped in bags, whereas the coarser

Table 5. World production of feldspar, 1975-76

	1975	1976[e]
	(tonnes)	
United States	608 000	658 000
Norway	259 000	272 000
West Germany	245 000	259 000
Italy	185 000	195 000
France	181 000	191 000
Japan	39 000	41 000
Sweden	32 000	36 000
Other countries	1 019 000	1 070 000
Total	2 568 000	2 722 000

Source: U.S. Bureau of Mines Commodity Data Summaries, January 1977.
[e]Estimated.

glass-grade is shipped in bulk to European markets. The company employs a modern fleet of coasters on long-term charter, and ships finished products to storage and distribution centres in major market areas.

Nepheline syenite is an important source of alumina for aluminum production in the U.S.S.R. Very large deposits occur near Kirovsk in the Kola Peninsula and also in the Lake Baikal region of Siberia. The Kola deposits were first mined in the 1930s for phosphate. Byproduct nepheline that contains 30 per cent Al_2O_3 is recovered for use in aluminum production. In the process used to extract alumina, limestone is added to the nepheline concentrates and the mix is sintered and treated with caustic soda to yield anhydrous alumina, soda, potash and cement. Aluminum producers elsewhere in the world, faced with rising bauxite prices and concerned about raw material supply, are viewing with interest potential alternate domestic sources of alumina, such as nepheline syenite, and anorthosite.

Feldspar still retains a major share of its traditional markets outside of North America, although Norwegian nepheline syenite is rapidly making headway in these markets. World production of feldspar in 1976 is an estimated 2.7 million tonnes.

Outlook

The outlook for nepheline syenite continues to be good, although the current recession in the world economy interrupted growth. Housing starts in Canada, at 273 203 in 1976, were up a surprising 18 per cent over 1975 starts and an upturn in United States housing construction also occurred. This industry, of course, is a major consumer of glass, sanitary-ware, paint, etc., and accordingly accounts in major part for the 16 per cent improvement in nepheline syenite shipments. Canadian shipments to Europe and Australia, the two largest offshore markets for nepheline syenite, rose 11 per cent and 8 per cent respectively, but these remain well below corresponding 1974 figures. However, these account for less than 5 per cent of Canada's total sales and, therefore, have little effect on overall developments in the industry.

Over the last several years, the market for micronized material used as a filler and extender in plastics, paint, rubber and paper has grown more rapidly than consumption for glassmaking, and further diversification and growth of these markets is expected.

The phenomenal growth rate enjoyed by the nepheline syenite industry during the 1950s and early 1960s has moderated as markets formerly supplied by feldspar approach saturation. The near-term hiatus in growth is a temporary one, and, with the recovery of the glass industry and continued expansion of other uses, a growth rate of 5 per cent a year is anticipated for the medium term.

With increasing electrical energy requirements, the demand for essential feldspar could elevate this raw material to a position of prime importance. The present slackness in the economy has eased these pressures temporarily, but rising prices and growing markets could provide an opportunity to develop a suitable Canadian deposit in the near future.

Prices

Nepheline syenite prices vary from low-purity, crushed rock, in bulk, at about $6.00 a ton, to over $30.00 a ton for high-purity products. The price of nepheline syenite used in the glass industry is around $17.00 a ton fob plant. The largest export market is the United States, where entry is duty free.

United States feldspar prices in U.S. currency as quoted in "Engineering and Mining Journal", December 1976.

(per short ton, fob mine or mill, carload lots, depending on grade).

	($ U.S.)
North Carolina	
40 mesh, flotation	27.50-29.00
20 mesh, flotation	18.75
200 mesh, flotation	28.75-41.00
Georgia	
200 mesh	40.00
40 mesh, granular	27.50
Connecticut	
200 mesh	28.00-30.00
20 mesh, granular	22.50

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
29600-1	Feldspar, crude	free	free	free	free
29625-1	Feldspar, ground but not further manufactured	free	7½%	30%	free
29640-1	Ground feldspar for use in Canadian manufactures (July 1, 1974 to June 30, 1984)	free	free	30%	free

United States

Item No.		
522-31	Crude feldspar	free
522-41	Feldspar, crushed, ground or pulverized	3.5%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedule of the United States Annotated (1976) T.C. Publication 749.

Nickel

M.J. GAUVIN

Canada's production of nickel in 1976 was 239 812 tonnes valued at $1 129.1 million compared with 242 180 tonnes* valued at $1 100.5 million in 1975. The increase in value is due to higher world prices for nickel. World mine production is estimated at 745 000 tonnes in 1976 compared with 751 000 tonnes in 1975. During 1976, Canada, the world's largest producer of nickel, accounted for 32.1 per cent of the world total. The U.S.S.R., with about 17 per cent of world production, and New Caledonia, with an estimated 14 per cent, were the two next-largest producers.

The slow rate of recovery from the recent worldwide recession produced a modest upturn in demand which increased world nickel shipments compared with 1975. However, with world production significantly higher than consumption, producers' inventories continued to grow above the high level held at the end of 1975. Some major producers reduced their production but newer producers in Botswana, Australia and the Philippines improved their operating efficiencies and were operating close to capacity at year-end. Consumption of nickel in the non-communist world in 1976 was about 495 000 tonnes. The comparable usage in 1975 was 415 800 tonnes.

There was a 21-cent-a-pound increase in the price of electrolytic nickel during 1976. The increase was announced during September and became effective at the end of December.

Canadian operations and developments

Six companies mined nickel ores in Canada during 1976. The largest producer was Inco Limited which operated mines in Ontario and Manitoba. Falconbridge Nickel Mines Limited, the second-largest producer, treated ores from its mines located in the same provinces. Inco, Falconbridge and Sherritt Gordon Mines Limited each have integrated mine-concentrator-smelter and refinery complexes where they processed ore to the metal stage. The three other concentrate producers operated mines in Ontario and Manitoba.

Three Canadian nickel producers ceased operations during the year. Kanichee Mining Incorporated stopped production in February at its copper-nickel mining operations at Temagami, Ontario after it received notification that its smelter contract was to be terminated. Dumbarton Mines Limited closed its operations on the Bird River claims of Maskwa Nickel Chrome Mines Limited in eastern Manitoba because of economic reasons. After 22 years of operation, Sherritt Gordon Mines Limited ceased operations at its Farley mine at Lynn Lake, Manitoba because of heavy operating losses. Ore reserves were limited at the time of closure and the mill and surface plant was mothballed to permit reactivation if a new ore discovery is made in the area.

Inco Limited is the world's largest producer of nickel. In 1976 it produced 209 561 tonnes of finished primary nickel products compared with 208 200 tonnes in 1975. In Ontario the company operated 11 mines, four concentrators, two smelters and a nickel refinery in the Sudbury district, a mine and concentrator at Shebandowan, northwestern Ontario, and a nickel refinery and additive plants at Port Colborne. In Manitoba, Inco operated three mines, a concentrator, a smelter and a refinery at Thompson. During 1976 development continued on two mines in the Sudbury area: the Levack East mine where production is scheduled to begin in 1983, and the Clarabelle open-pit extension which is expected to resume production in 1978. Three mines, the Totten and Murray in Ontario and the Soab in Manitoba, were maintained on a standby basis. The proven ore reserves of the company in Canada are 374 million tonnes containing 6.2 million tonnes of nickel and 4.4 million tonnes of copper.

A new rolling mill is being built by Inco in the Sudbury district. It will produce, by the direct rolling of metal powders, nickel and cupro-nickel alloy strip, primarily for coinage. Construction of the $29 million facility started in March 1976 and is scheduled to go into production in the second half of 1977.

Falconbridge Nickel Mines Limited operated four mines, two concentrators, and one smelter in the Sudbury area of Ontario. In Manitoba the company operated the Manibridge mine and concentrator . Production cutbacks that were effected near the end of 1975 carried on through 1976. Four mines and one concentrator in Sudbury were maintained on a standby basis. At the end of 1976 work was underway to reactivate the Longvack South mine . Two major capital expenditure programs which had been suspended in 1975 were reactivated during the year.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Development of the Fraser mine on the north rim of the Sudbury basin was restored to an active basis. Construction work was also resumed on $95 million smelter environmental and efficiency improvement program at the Sudbury operations, with the completion of construction scheduled for the spring of 1978. The Strathcona mill expansion program was completed, raising its capacity to 7 700 tonnes a day . Development work continued at the Lockerby property and by year-end , ore production had reached 40 per cent of its design capacity of 58 000 tonnes a month.

Sherritt Gordon closed its Lynn Lake mine in June because it was no longer economic. Underground salvage work continued for the balance of the year and the mill was moth-balled and left in standby condition. Sherritt's Fort Saskatchewan refinery operated at about the same level as in 1975. With the closure of the Lynn Lake mine, the refinery is now totally dependent on outside feed.

The Langmuir mine near Timmins, Ontario, owned by Noranda Mines Limited and Inco, produced 3 175 tonnes of nickel contained in concentrates. A decline from surface was started to explore and develop the number 1 ore zone. Ore reserves at the property are 588 500 tonnes grading 1.30 per cent nickel.

Union Minière Explorations and Mining Corpora-

Table 1. Canada, nickel production, trade and consumption, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production[1]				
All forms				
Ontario	179 095	811 328 713	188 904	890 704 000
Manitoba	63 085	289 194 067	50 908	238 439 000
British Columbia				
Total	242 180	1 100 522 780	239 812	1 129 143 000
Exports				
Nickel in ores, concentrates and matte[2]				
United Kingdom	45 565	207 401 000	37 119	173 538 000
Norway	31 078	117 160 000	26 893	106 104 000
Japan	7 747	30 656 000	8 545	35 765 000
United States	1	5 000	18	56 000
Total	84 391	355 222 000	72 575	315 463 000
Nickel in oxide				
United States	16 519	63 541 000	28 683	. .
Belgium-Luxembourg	6 966	28 789 000		
Italy	5 350	21 697 000		
United Kingdom	4 712	19 147 000		
Sweden	1 681	6 714 000	EEC } 11 582	. .
West Germany	1 067	4 194 000		
Spain	1 006	4 062 000		
Other countries	1 226	5 189 000	7 693	. .
Total	38 527	153 333 000	47 958	200 619 000
Nickel and nickel alloy scrap				
United States	1 287	3 629 000	1 550	3 588 000
Italy	887	2 767 000	727	3 422 000
Netherlands	67	125 000	126	281 000
Japan	—	—	30	99 000
Argentina	—	—	16	78 000
Other countries	978	1 040 000	53	111 000
Total	3 219	7 561 000	2 502	7 579 000

Table 1 (cont'd)

	1975		1976ᵖ	
	(tonnes)	($)	(tonnes)	($)
Nickel anodes, cathodes, ingots, rods				
United States	68 301	279 472 000	63 849	..
United Kingdom	15 092	61 273 000		
Japan	1 109	4 563 000		
France	1 127	4 189 000		
India	894	3 948 000	EEC } 13 636	..
Australia	790	3 598 000		
Brazil	649	2 929 000		
Mexico	507	2 223 000		
People's Republic of China	500	2 160 000		
Netherlands	411	1 775 000		
Argentina	295	1 339 000		
Other countries	1 063	4 776 000	10 225	..
Total	90 738	372 245 000	87 711	388 957 000
Nickel and nickel alloy fabricated material, nes				
United States	7 343	30 929 000	8 994	44 171 000
United Kingdom	1 945	8 173 000	1 063	4 641 000
Japan	67	326 000	342	1 617 000
Australia	88	424 000	163	763 000
Hungary	—	—	109	621 000
Sweden	3	14 000	117	498 000
Italy	—	—	83	339 000
Other countries	305	1 537 000	352	1 623 000
Total	9 751	41 403 000	11 223	54 273 000
Imports				
Nickel in ores, concentrates and scrap				
Australia	8 678	29 168 000	15 333	35 430 000
United States	5 813	9 760 000	5 449	6 729 000
United Kingdom	2 133	2 102 000	8 432	6 130 000
South Africa	—	—	149	469 000
Belgium-Luxembourg	91	109 000	97	140 000
Switzerland	46	41 000	47	47 000
Other countries	1 133	3 894 000	30	42 000
Total	17 894	45 074 000	29 537	48 987 000
Nickel anodes, cathodes, ingots, rods				
Norway	12 783	58 468 000	16 417	82 168 000
United States	38	260 000	393	1 966 000
West Germany	26	168 000	12	66 000
Other countries	—	—	7	38 000
Total	12 847	58 896 000	16 829	84 238 000
Nickel alloy ingots, blocks rods and wire bars				
United States	513	2 411 000	477	2 560 000
United Kingdom	2	16 000	2	7 000
Other countries	7	41 000	—	—
Total	522	2 468 000	479	2 567 000

Table 1 (concl'd)

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Nickel and alloy plates, sheet, strip				
United States	2 597	19 360 000	1 817	12 539 000
West Germany	47	425 000	147	907 000
United Kingdom	81	470 000	11	38 000
Other countries	17	109 000	6	26 000
Total	2 742	20 364 000	1 981	13 510 000
Nickel and nickel alloy pipe and tubing				
West Germany	207	3 449 000	501	6 246 000
United States	646	5 243 000	718	5 817 000
Other countries	115	1 760 000	185	3 555 000
Total	968	10 452 000	1 404	15 618 000
Nickel and alloy fabricated material, nes				
United States	390	3 571 000	385	3 432 000
South Africa	—	—	135	610 000
United Kingdom	93	697 000	35	325 000
Other countries	23	141 000	49	277 000
Total	506	4 409 000	604	4 644 000
Consumption[3]	11 307		9972	

Source: Statistics Canada; Department of Energy, Mines and Resources, Ottawa.
[1]Refined nickel and nickel in oxides and salts produced, plus recoverable nickel in matte and concentrates exports. [2]For refining and re-export. [3]Consumption of nickel, all forms (refined metal and in oxide and salts) as reported by consumers.
pPreliminary; — Nil; . . Not available.

tion Limited (UMEX) started production in August at its Thierry deposit near Pickle Lake, Ontario. Initial feed for the 3 600 tonne-a-day concentrator will come from two open pits while the underground mine is prepared for production. The Thierry ore reserves contain a minor amount of nickel which is recovered in the copper concentrate.

World developments

World mine production decreased from 751 000 tonnes in 1975 to an estimated 745 000 tonnes in 1976.

The Selebi-Pikwe project of Bamangwato Concessions Ltd. in Botswana is slowly overcoming its start-up problems and is expected to be operating at its rated capacity of 36 million pounds of nickel contained in matte early in 1977. When it reaches capacity its output will represent about half of the requirements of the Port Nickel, Louisiana, refinery of AMAX Inc. Ore is supplied to the Bamangwato plant from the Pikwe open-pit and underground mine. The Selebi mine is scheduled to start production in 1979. The refinery at Port Nickel uses an Amax-developed acid leach process to produce nickel briquettes and has a capacity of 80 million pounds of nickel a year. The refinery is expected to reach capacity in 1977.

Marinduque Mining and Industrial Corporation, in which Sherritt Gordon Mines, Limited has a 10 per cent interest, made good progress in overcoming its initial start-up difficulties at the Philippine facilities and is expected to be operating next year at close to its rated capacity. The refinery utilizes the Sherritt Gordon hydrometallurgical process for producing nickel from laterite ores. Design capacity of the plant is 68.4 million pounds of refined nickel in the form of briquettes and powder, plus mixed sulphide concentrates containing an additional 6.6 million pounds of nickel. Rio Tuba Nickel Mining Corporation expects to start shipping ore to Japan in 1977 from its Pulawan Island, Philippine, mine. Shipments are to be 315 000 tonnes of ore in 1977, rising to 450 000 tonnes in 1978. Reserves at Rio Tuba are estimated at 20 million tonnes averaging 2.2 per cent nickel.

Inco Limited (Inco) is developing two laterite projects. One of these is in Guatemala, where Inco, through Exploraciones y Explotaciones Mineras Izabal, S.A. (Exmibal) is nearing completion of plant con-

CANADIAN NICKEL PRODUCTION by PROVINCES

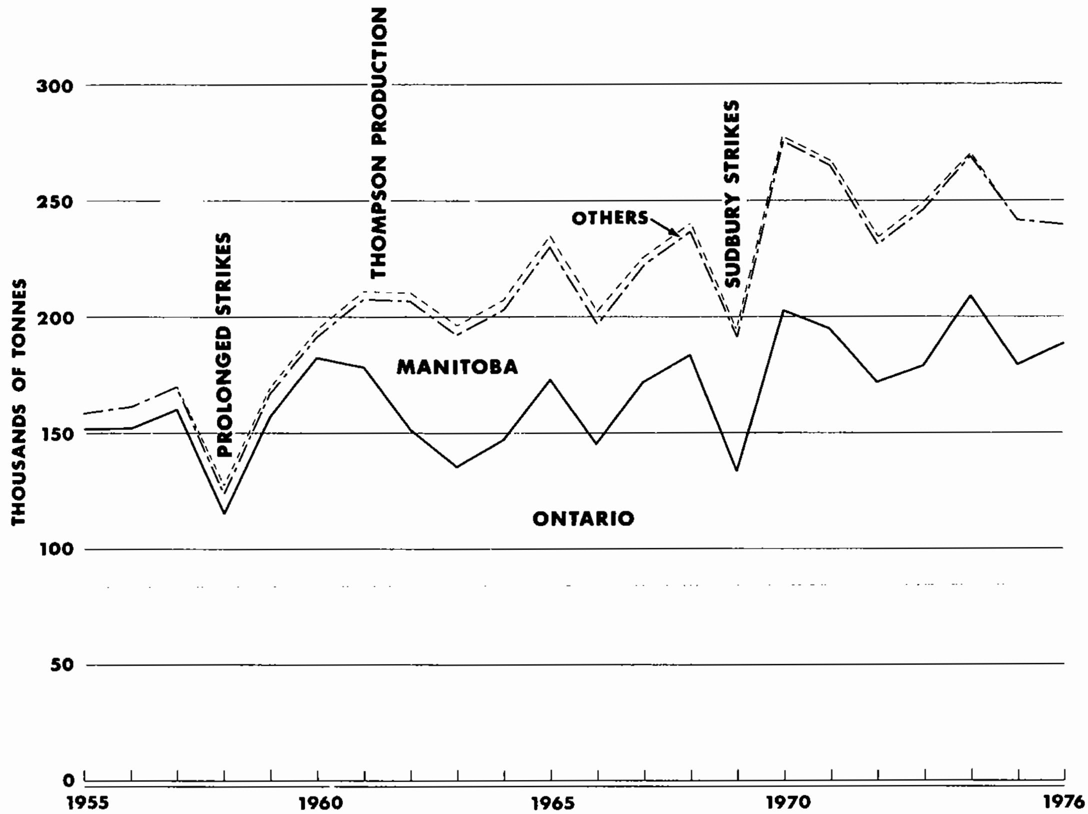


Table 2. Nickel production, trade and consumption, 1965, 1970 and 1974-76

		Exports					
	Production[1]	In matte etc.	In Oxide Sinter	Refined Metal	Total	Imports[2]	Consumption[3]
		255·20	253·30	454·15 (tonnes)		454·15	
1965	235 126	74 686	37 154	122 649	234 489	11 042	8 096
1970	277 490	87 688?	39 821	138 983	266 492	10 728	10 699
1974	269 071	85 240	51 118	120 344[r]	256 702	15 233	11 567
1975	242 180	84 391	38 527	90 738	213 656	12 847	11 307
1976[p]	239 812	72 575	47 958	87 711	208 244	16 829	. .

Sources: Statistics Canada; Department of Energy, Mines and Resources, Ottawa.
[1]Refined metal and nickel in oxide and salts produced, plus recoverable nickel in matte and concentrates exported. [2]Refined nickel, comprising anodes, cathodes, ingots, rods and shot. [3]Consumption of nickel, all forms (refined metal, and in oxides and salts), as reported by consumers.
[p]Preliminary; . . Not available; [r]Revised.

struction at its Lake Izabal laterite deposit. The plant will include a smelter with an annual capacity of 28 million pounds of nickel contained in a sulphide matte. Production is scheduled to start in 1977. Exmibal is owned 80 per cent by Inco and 20 per cent by The Hanna Mining Company, with provisions for the Guatemalan government and private Central American interests to eventually acquire up to 36 per cent. The estimated cost of the project is $224 million. In Indonesia, P.T. International Nickel Indonesia continued construction on the first stage of development of the Malii-Soroaka deposits on Sulawesi Island, expected to begin production early in 1977. Annual capacity of the first stage of the project will be 35 million pounds of nickel contained in a 75 per cent nickel matte. The second stage, which includes a hydroelectric plant on the Larona River, will increase nickel production capacity to over 100 million pounds in 1979. Total cost of the completed project is now estimated at $850 million. This amount provides for an additional 55-megawatt generating unit at the hydroelectric plant, raising its total capacity to 165 megawatts.

The Australian Greenvale laterite-nickel project of Freeport Minerals Company and Metals Exploration N.L. that started production near the end of 1974 has overcome a series of problems which at times threatened closure. Greenvale is now operating at its rated capacity of 20 865 tonnes of nickel in the form of 90 per cent nickel oxide sinter, plus 3 400 tonnes of nickel contained in mixed sulphides. Agnew Mining Co. (Pty) Ltd., owned by British Selection Trust and M-I-M Holdings Limited, has started development and construction at its Agnew deposit with a view to bringing it into production late in 1978. It will have initial capacity of 10 000 tonnes of nickel contained in concentrates a year. The concentrates will be shipped to the Kalgoorlie, Western Australia, smelter of Western Mining Corporation Limited. Western Mining has announced plans to install a new flash smelter with a capacity of 450 000 tonnes of concentrate a year. This will give Western sufficient capacity to treat the Agnew concentrates and to increase its own mine output after 1979. Western Mining has completed the expansion of its Kwinana refinery from 20 000 to 30 000 tonnes of nickel a year, and a further 50 per cent increase in its capacity is being considered.

Société Métallurgique Le Nickel (SLN) is in the process of expanding its Doniambo, New Caledonia, plant from 70 000 to 81 000 tonnes a year by 1980. A further increase to 91 000 tonnes is planned for the early 1980s. SLN is also building a new refinery at Le Havre, France, with a capacity to produce 13 500 tonnes of high-purity nickel a year. It is scheduled to begin production in 1978.

Falconbridge Dominicana, C por A continued ferronickel production at its Dominican Republic laterite property. The company operated at a reduced production rate during the year to conform with reduced demand.

United Nations — Law of the Sea

Two sessions of the third United Nations Conference on the Law of the Sea (LOS) were held during the year. One of the aims of the Conference is to reach a consensus as to how the mineral resources of the deep sea-bed, principally manganese nodules containing substantial quantities of nickel, copper and cobalt, are to be developed and managed. During the spring session a so-called production control formulation keyed to nickel appeared in the Revised Single Negotiating Text. This formulation, in the form of a control on sea-bed mining, would limit the production of sea-bed nickel to an amount equal to the growth in world demand of nickel, provided, however, that the increase in demand is computed as at least 6 per cent per year. An alternative formula has been proposed by the developing countries, known as the Group of 77. This proposal would limit total annual sea-bed production to an amount not greater than one-half of the average actual annual increase in world demand, thus putting forth a concept of sharing new demand between land- and sea-based mining. Negotiations at the Conference have been prolonged over many issues, including who will mine the resources of the ocean, the rules under which the deposits would be exploited and who will benefit from the production.

Uses

Nickel uses have not changed appreciably from the traditional pattern. Resistance to corrosion, high strength over a wide temperature range, pleasing appearance and suitability as an alloying agent are the chief advantages in almost all the use of nickel.

Stainless steel is the largest single outlet for nickel, followed by nickel plating and high-nickel alloys. Stainless steel use has increased in the field of rapid transit and railway car manufacture, in fertilizer and food processing machinery, in petroleum refining and in architectural applications. High-nickel alloys are used in chemical, marine, electronic, nuclear and aerospace applications.

New end-use markets which will contribute to nickel's consumption growth are nuclear generating plants, gas turbine engines for surface applications, cryogenic containers, pollution abatement equipment, barnacle-resisting, copper-nickel alloy hull-plating for boats and nickel-cadmium batteries for standby power application. Long life zinc-nickel batteries are being developed to power electric automobiles.

(text continued on page 382)

Table 3. Producing Canadian nickel mines, 1976 and (1975)

Company and Location	Mill or Mine Capacity	Grade of Ore: Nickel	Grade of Ore: Copper	Ore Produced	Contained Nickel Produced	Remarks
	(tonnes ore/day)	(%)	(%)	(tonnes)	(tonnes)	
Ontario						
Falconbridge Nickel Mines Limited	12 790	. .	. .	2 920 568	37 927[1]	Operating rate was curtailed
Falconbridge, Strathcona, Hardy	(12 700)	(. .)	(. .)	(2 759 000)	(29 564)[1]	throughout the year. Major capital
Open Pit and North mines	2 720	(Falconbridge)				projects, suspended in 1975, were
Falconbridge	7 710	(Strathcona)				resumed.
	2 360	(Fecunis Lake)				
Inco Limited	59 000	1.41[2]	0.97[2]	14 949 682[3]	185 897[4]	Development work continued on
Coleman, Copper Cliff North,	(59 000)	(1.40)[2]	(0.92)[2]	(15 593 656)[3]	(159 266)[4]	the Levack East and Clarabelle
Copper Cliff South, Crean Hill,	31 800	(Clarabelle)				open-pit extensions.
Creighton, Frood-Stobie, Garson,	21 800	(Frood-Stobie)				The Clarabelle is expected to
Kirkwood, Levack, Levack West,	5 400	(Levack)				resume production in 1978 and
Little Stobie and Victoria mines	10 300	(Creighton —				Levack East to start production in
Sudbury		not operating)				1983. The Kirkwood mine was
						mined out during the year.
Shebandowan mine	2 270	. .	. .	See above[3]	see above[4]	
Shebandowan	(2 270)	(. .)	(. .)	See above[3]	see above[4]	
Kanichee Mining Incorporated	450	. .	. .	5 213	20	Smelter contract cancelled and
Temagami	(450)	(0.50)	(0.72)	(136 138)	(413)	production stopped in February
Noranda Mines Limited	635	1.51	. .	250 357	3 175	Continued development of No. 1
Langmuir Township	(635)	(1.46)	(. .)	(237 256)	(2 782)	zone.
Union Minière Explorations and	3 600	0.10	1.14	230 610	52	Concentrator commenced
Mining Corporation Limited	(—)	(—)	(—)	(—)	(—)	operation during August, 1976.
Thierry mine						
Pickle Lake						

Table 3 (concl'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Nickel	Grade of Ore Copper	Ore Produced	Contained Nickel Produced	Remarks
	(tonnes ore/day)	(%)	(%)	(tonnes)	(tonnes)	
Manitoba						
Dumbarton Mines Limited	–	1.04	0.29	128 112	1 005	Production stopped at mid-year
Maskwa East & West Extensions	–	(1.10)	(0.23)	(321 604)	(2 577)	for economic reasons
Bird River						
Falconbridge Nickel Mines Limited	9 070	. .	. .	188 995	see above[1]	Ore reserves near exhaustion.
Manibridge mine	(9 070)	(. .)	(. .)	(171 275)	see above[1]	Operations to cease in the first
Waboden						half of 1977
Inco Limited	16 700	see above[2]	see above[2]	2 751 960	see above[4]	Development continued at the
Birchtree, Pipe and Thompson mines	(16 700)	(see above)[2]	(see above)[2]	(3 417 739)	see above[4]	three operating mines. Soab mine
Thompson						maintained on a standby basis.
Sherritt Gordon Mines Limited	3 200	0.97	0.42	178 980	1 407	Mine closed after 22 years of
Lynn Lake	(3 200)	(0.84)	(0.38)	(318 910)	(2 600)	operation. Mill and surface plant
						mothballed.

Sources: Company annual reports, and data provided by companies.
[1]Total nickel deliveries, includes Manibridge; [2]Includes Manitoba division; [3]Includes Shebandowan; [4]Total nickel deliveries.
. . Not available; – Nil.

Table 4. Prospective[1] Canadian nickel mines

Company and Location	Mill Capacity[2] and Ore Grade	Year Production Expected	Destination of Nickel Concentrates	Remarks
	(%)			
Quebec				
Renzy Mines Limited Hainault Township	900 Ni (0.69) Cu (0.72)	. .	. .	Surface buildings destroyed by fire in 1974 will have to be rebuilt.
Ontario				
Falconbridge Nickel Mines Limited, Falconbridge	. . Ni (. .) Cu (. .)		Falconbridge	
Fraser mine		. .		
Thayer Lindsley mine		. .		Deferred.
Onex mine		. .		Deferred.
Inco Limited Sudbury	. . Ni (. .) Cu (. .)		Sudbury	
Clarabelle mine		1978		Open-pit mining completed in 1974. Mining will be resumed upon development of ore extension.
Levack East		1983		Development continuing.
Murray mine		. .		Suspended and placed on standby in 1971.
Totten mine		. .		Development suspended and placed on standby in 1972.
Great Lakes Nickel Limited, Pardee Township	96 000 000 tonnes ore reserves Ni (0.20) Cu (0.40)			The development work to bring the property into production at a rate of 1.8 million tpy has been suspended and the project put on standby.
Manitoba				
Inco Limited Thompson, Soab mine	— Ni (. .) Cu (. .)	. .	Thompson	Production suspended and placed on standby in 1971.

Sources: Company annual reports and technical press.
[1]Mines with announced production plants. [2]Mill capacity in tonnes of ore a day.
. . Not available; — Nil.

Outlook

The slow recovery of the economies of the major nations from the severe recession the world has recently experienced is expected to continue. However, it will still be some time before there is a strong upturn in capital construction, which would quickly raise the level of nickel consumption. Producers' stocks are expected to remain high during 1977 with the industry as a whole operating at a level well below capacity. Three new producers will be coming on stream in 1977 and several more producers, as well as expansions of current capacity, will be operational by 1980. This new capacity will supply the expected growth of nickel markets into the early 1980s.

Looking further into the future a cloud of uncertainty arises, especially as to the role that ocean nodules will play in supplying future increases in world nickel demand. The economic extraction of nickel from seabed nodules is a long-term proposition. The possibility of technological failure or uneconomic operation still exists. This picture may change if major subsidies were to be considered and implemented. Meanwhile, damage to long-term supply patterns may be done, since as long as this uncertainty exists it may tend to inhibit the expansion of land-based production, particularly in view of the low profitability the industry has shown in the last few years. The industry also faces uncertain health and safety standards and environmental controls in a number of countries. The resolution of these problems would assist in clarifying investment decisions and assure an adequate supply to meet long-term demand.

Table 5. Nickel exploration projects*

Company and Location	Indicated Ore	Grade of Ore
	(tonnes)	(%)
Quebec		
Dumont Nickel Corporation Launey Township	14 000 000	0.646 (Ni)
New Quebec Raglan Mines Limited Ungava	14 500 000	2.58 (Ni) 0.71 (Cu)
Ontario		
Teck Corporation Limited, Metallgesellschaft Canada Limited, and Domik Exploration Limited Montcalm Township	. .	. .
Manitoba		
Bowden Lake Nickel Mines Limited Wabowden		
Bowden Lake mine	72 000 000	0.60 (Ni)
Bucko Lake mine	27 000 000	0.78 (Ni)
Saskatchewan		
National Nickel Ltd. and Cadillac Exploration Limited Nemeiben Lake, La Ronge	4 970 000	0.34 (Ni) 0.18 (Cu)
Uranerz Exploration and Mining Limited, Inexco Mining Company and Saskatchewan Mining Development Corporation. Key Lake	. .	. .

*Does not include undeveloped deposits in the Sudbury, Ontario, area.
Sources: Company annual reports and technical press.
. . Not available.

Table 6. World production of nickel, 1975-76

	1975	1976[e]
	(tonnes)	
Canada[1]	242 180	239 180
U.S.S.R.	125 000	125 000
New Caledonia	133 300	106 600
Australia	75 800	85 400
Cuba	36 600	36 800
Dominican Republic	26 900	26 900
South Africa	20 800	22 300
Greece	14 800	17 200
United States	15 400	15 600
Indonesia	14 600	12 600
Rhodesia	10 000	10 000
Finland	5 700	6 500
Brazil	3 200	3 200
East Germany	2 500	2 400
Other	24 220	35 300
Total	751 000	744 980

Sources: World Bureau of Metal Statistics, April, 1977. Statistics Canada, for Canada.
[e] Estimated. [1] Production all forms.

Prices

There was one change in the quoted price of nickel during 1976. At the beginning of the year refined nickel was quoted at $2.20 a pound and Class II (ferronickel and oxide sinter) was quoted in a price range of $2.07 to $2.19 a pound.

In September and early October, producers announced price increases that became effective at the end of the year. The new prices increased the quoted price of electrolytic nickel by 21 cents a pound and Class II products by 18 to 20 cents a pound . However, competition within the industry forced producers in the last quarter of the year to offer special discounts on firm orders received before the year-end for 1977 delivery.

Table 7. Prospective world nickel producers

Country Company Mine	Annual Capacity	Announced Date of Production	Destination of Concentrates	Remarks
	(tonnes of contained nickel)			
Australia				
Selection Trust Limited and M-I-M Holdings Agnew deposit Western Australia	10 000	1978	Kalgoorlie Western Australia	Mine development, surface plant and townsite construction started in 1976.
Metals Exploration N.L. and Freeport of Australia Mount Keith Western Australia	. .	. .	. .	Ore reserves are 300 000 000 tonnes averaging 0.6 per cent nickel.
Brazil				
Cia Vale do Rio Doce Piaui State	5 400	. .	own smelter	Company plans to build smelter near the ore deposit.
Baminco Mineracao e Siderurgia, S.A. and Inco, and West German consortium Barro Alto deposit Goias State	. .	. .	. .	Feasibility study in progress.
Colombia				
The Hanna Mining Company, Compania Niquel Chevron and Industrial Development Institute of Colombia. Cerro Matoso deposit.	22 500	. .	own smelter	Pilot plant tests and feasibility studies completed. Negotiations in progress which may lead to production in 1980.
Cuba				
Cuban government Cuban deposits	30 000 60 000	1975-1980 1980-1985	own smelter own smelter	Three new plants each with a capacity of 30,000 tpy to be brought into production between 1975 and 1985.
Greece				
Intercontinental Mining and Abrasives, Inc. and Southland Mining Company Lake Ionina	. .	. .	. .	
Larco Larymna area	32 400	. .	own smelter	Expansion of current capacity of 16 200 tpy.

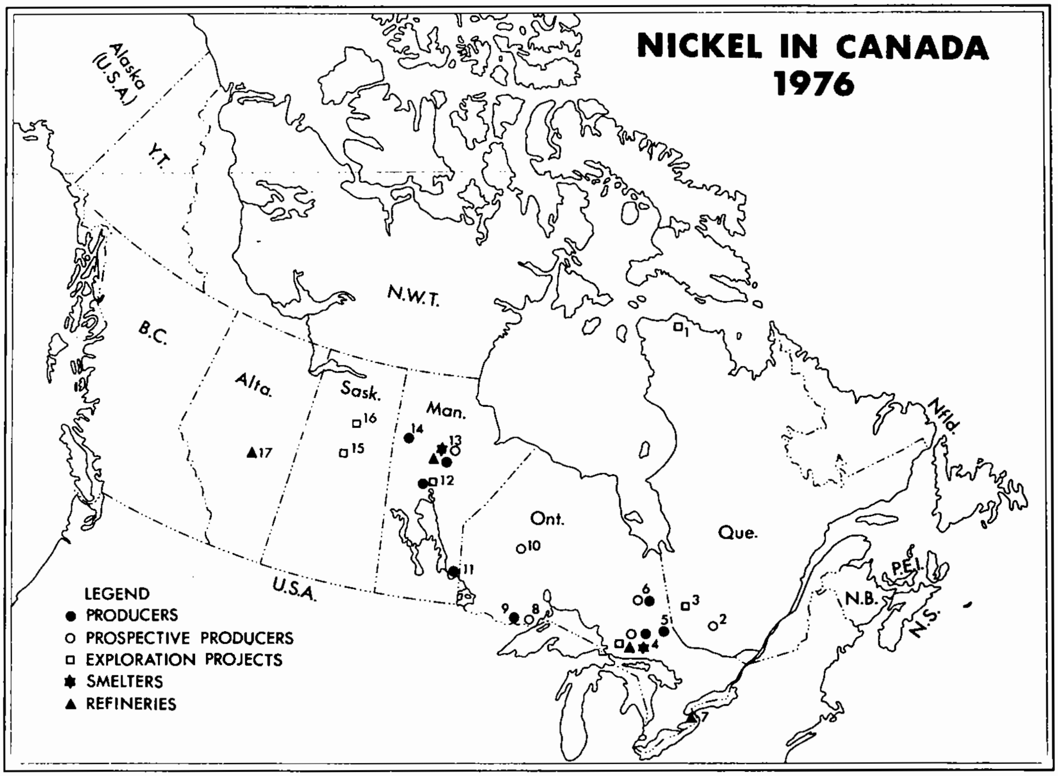
Table 7 (cont'd)

Country Company Mine	Annual Capacity	Announced Date of Production	Destination of Concentrates	Remarks
	(tonnes of contained nickel)			
Guatemala				
Exploraciones y Explotaciones Mineras Izabal, S.A. (Exmibal) Lake Izabal	12 600	1977	own smelter	
India				
Hindustan Copper Ltd., Sukinda deposit Orissa State	4 300	1979	own smelter	
Indonesia				
Indonesian Nickel Development Company (Indeco) Gebe Island	23 400	. .	own smelter	Ore reserves of 29 million tonnes grading 2.2% nickel.
P.T. International Nickel Indonesia Soroako deposit Sulawesi Island	15 800	1977	own smelter	Capacity to be expanded to 45 000 in 1978.
P.T. Pacific Nikkel Indonesia Gag Island Irian Barat	45 000	. .	own smelter	
New Caledonia				
Société Métallurgique le Nickel	81 000	1980	own smelter	The Doniambo plant is being expanded from 70 000 tonnes and a further expansion to 90 000 tonnes is planned in the early 1980s.
AMAX Inc. and Société Minière et Métallurgique de Penarroya, S.A. (Penamax) Goro deposit	22 500	. .	Port Nickel, Louisana, U.S.A.	
Puerto Rico				
Universal Oil Products Co. Guanajibo deposit	13 500	. .	. .	In feasibility stage.
Republic of the Philippines				
Atlas Consolidated Mining and Development Palawan Island	16 000	. .	own smelter	
Rio Tuba Nickel Mining Palawan Island	9 000	1977	Japan	Annual shipments of 500 000 tons of garnierite ore.
Venezuela				
Société Le Nickel and Venezuelan Government Loma de Hierro	18 000	. .	own smelter	

Table 7 (concl'd)

Country Company Mine	Annual Capacity	Announced Date of Production	Destination of Concentrates	Remarks
	(tonnes of contained nickel)			
Yugoslavia				
Government company Kavadarci deposit Macedonia	10 800	1979	own smelter	Ferronickel.
Golos and Cikatovo deposits Kosovo	9 000	1978	own smelter	Ferronickel.

Sources: Company annual reports and technical press.
. . Not available.



Producers

(numbers appear on map above)

4. Falconbridge Nickel Mines Limited (Hardy open pit, Falconbridge, North and Strathcona mines)
   Inco Limited (Coleman, Copper Cliff North, Copper Cliff South, Crean Hill, Creighton, Frood-Stobie, Garson, Kirkwood, Levack, Levack West, Little Stobie, and Victoria mines)
5. Kanichee Mining Incorporated (Temagami)

6. Noranda Mines Limited (Timmins)
9. Inco (Shebandowan mine)
10. Union Minière Explorations and Mining Corporation Limited (Pickle Crow)
11. Dumbarton Mines Limited (Bird River)
12. Falconbridge Nickel Mines Limited (Manibridge mine)
13. Inco (Birchtree, Pipe and Thompson mines)
14. Sherritt Gordon Mines Limited (Lynn Lake)

Prospective Producers

2. Renzy Mines Limited (Hainault Township)
4. Falconbridge Nickel Mines Limited (Fraser, Lockerby, Onex and Thayer Lindsley mines)
   Inco (Clarabelle, Murray, Levack East and Totten mines)
8. Great Lakes Nickel Limited (Pardee Township)
13. Inco Limited (Soab mine)

Nickel Exploration Projects

1. New Quebec Raglan Mines Limited (Ungava) and Expo Ungava Mines Limited (Ungava)
3. Dumont Nickel Corporation (Launay Township)
4. Inco (Cryderman, North Range and Whistle mines)
6. Teck Corporation Limited (Montcalm Township)
12. Bowden Lake Nickel Mines Limited (Bowden Lake and Bucko Lake mines)
15. National Nickel Ltd. and Cadillac Explorations Limited (Nemeiben Lake)
16. Uranerz Exploration and Mining Limited (Key Lake)

Smelters

4. Falconbridge Nickel Mines Limited (Falconbridge)
   Inco Limited (Sudbury)
13. Inco Limited (Thompson)

Refineries

4. Inco Limited (Sudbury)
7. Inco Limited (Port Colborne)
13. Inco Limited (Thompson)
17. Sherritt Gordon Mines Limited (Fort Saskatchewan)

Table 8. Producer prices for nickel quoted during 1976.

	January	December
	($ U.S. per pound)	
Falconbridge Nickel		
Electrolytic, fob Thorold, Ont., 20,000 lb lots	$2.20	$2.41
Ferronickel[1]	2.18	2.36
Inco Limited		
Electrolytic, fob Port Colborne, Ont.	2.20	2.41
Nickel oxide sinter 75[1]	2.07	2.27
"F" shot	2.23	2.42
Pellets	2.20	2.41
Sherritt Gordon		
Briquettes or powder, fob Niagara Falls, Ont. and Fort Saskatchewan, Alta. 20,000 lb lots	2.20	2.41
The Hanna Mining Company		
Ferronickel[1]	2.16	2.34
Société Métallurgique Le Nickel		
Rondelles	2.20	2.41
FNC[1]	2.17	2.37
FN3[1]	2.19	2.39
FN4[1]	2.15	2.35
Western Mining Corporation Limited		
Briquettes or powder	2.20	2.41

Sources: *The Northern Miner, Metals Week, American Metal Market.*
[1]Price applies to nickel content.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
32900-1	Nickel ores	free	free	free	free
33506-1	Nickelous oxide	10	15	25	10
35500-1	Nickel and alloys containing 60% or more nickel by weight, not otherwise provided for, viz: ingots, blocks, and shot; shapes or sections, billets, bars and rods, rolled, extruded or drawn (not including nickel processed for use as anodes); strip, sheet and plate (polished or not); seamless tube	free	free	free	free
35505-1	Rods containing 90% or more nickel, when imported by manufacturers of nickel electrode wire for spark plugs, for use exclusively in manufacture of such wire for spark plugs in their own factories	free	free	10	free
35510-1	Metal alloy strip or tubing, not being steel strip or tubing, containing not less than 30% by weight of nickel and 12% by weight of chromium, for use in Canadian manufacturers	free	free	20	free
35515-1	Nickel and alloys containing 60% by weight or more of nickel, in powder form	free	free	free	free
35520-1	Nickel or nickel alloys, namely: matte, sludges, spent catalysts and scrap and concentrates other than ores	free	free	free	free
35800-1	Anodes of nickel	free	free	10	free
37506-1	Ferronickel	free	5	5	free
44643-1	Articles of nickel or of which nickel is the component material of chief value, of a class or kind not made in Canada, when imported by manufacturers of electric storage batteries for use exclusively in manufacture of such storage batteries in own factories.	10	10	20	6½
92934-2	Nickel carbonyl, in liquid form, for use in the manufacture of moulds of nickel (expired Oct. 31, 1975)	free	free	25	free

No longer included in tariff classifications Revised March 1/76

United States

Item No.		On and after January 1, 1976
419.70	Nickel chloride	5%
419.72	Nickel oxide	free
419.74	Nickel sulphate	5%
419.76	Other nickel compounds	5%
423.90	Mixtures of two or more inorganic compounds in chief value of nickel oxide	free
426.58	Nickel salts: acetate	5%
426.62	Nickel salts: formate	5%
426.64	Nickel salts: other	5%
601.36	Nickel ore	free
603.60	Nickel matte	free
607.25	Ferronickel	free
620.03	Unwrought nickel	free
620.04	Nickel waste and scrap	free
620.08	Nickel plates and sheets, clad	12%
620.10	Other wrought nickel, not cold worked	5%
620.12	Other wrought nickel, cold worked	7%
620.16	Nickel, cut, pressed or stamped to nonrectangular shapes	9%
620.20	Nickel rods and wire, not cold worked	5%
620.22	Nickel rods and wire, cold worked	7%
620.26	Nickel angles, shapes and sections	9%
620.30	Nickel flakes	5¢ per lb.
620.32	Nickel powders	free
620.40	Pipes, tubes and blanks, not cold worked	3%
620.42	Pipes, tubes and blanks, cold worked	4%
620.46	Pipe and tube fittings	9%
620.47	If Canadian article and original motor vehicle equipment	free
620.50	Electroplating anodes, wrought or cast, of nickel	5%
642.06	Nickel wire strand	7%
657.50	Articles of nickel, not coated or plated with precious metal	9%

Sources: For Canada, the Customs Tariff and Amendments, Revenue Canada, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976) TC Publication 749.

Petroleum

W.G. LUGG

The year 1976 was one of little progress in the Canadian petroleum industry as crude oil reserves again declined, causing increased concern as to future domestic supply. Production of crude oil and natural gas liquids decreased for the third consecutive year due to federally-regulated reductions in crude oil exports to the United States that commenced in 1975. Consumption by domestic consumers increased, particularly in Quebec, where increasing volumes of western Canadian crude oil are being delivered to Montreal refineries via the Montreal-Sarnia extension of the Interprovincial pipeline which began operating in June 1976.

Regardless of production cutbacks, revenues from producer sales of crude oil, natural gas liquids and natural gas increased by $1256 million to an all-time high of $7314 million. The 20 per cent growth rate reflects a substantial increase in the wellhead price of crude oil as well as rises in both export and domestic natural gas prices. Crude oil and condensate accounted for $4024 million of this total while natural gas liquid wellhead sales amounted to $794 million. Expenditures for exploration and development, including royalty payments escalated by $1369 million to $5444 million. The gain in expenditures reflects a continuation of increased costs due to inflation, plus a 15 per cent gain in industry activity.

Exploration, particularly in Alberta, was at an all-time high. Stimulated by escalating crude oil and natural gas prices and provincial government drilling incentives, both exploratory and development drilling increased. The number of wells completed in 1976 was almost 35 per cent higher than in the same 1975 period, and metres drilled increased by 32 per cent. This major upturn in activity was reflected in the success obtained in Alberta, particularly in the Foothills regions where several significant gas discoveries were made. In the frontier areas, drilling activity declined, but noteworthy gas discoveries were recorded offshore from the Labrador coast and in the Beaufort Sea. There were no significant oil discoveries in 1976.

Refinery capacity was increased substantially in Canada in 1976, mainly with the completion of Irving Oil Limited's Saint John, N.B. refinery expansion to 39 747 m^3 (cubic metres) a day (250 000 b/d) from 19 080 m^3 a day (120 000 b/d). By 1978 refinery capacity will have increased to almost 397 500 m^3 a day (2.5 million b/d) with the completion of Texaco Canada Limited's 15 189-m^3-per-day (95 000 b/d) refinery at Nanticoke, Ont. and Petrosar Limited's large facility at Sarnia, Ont. Notwithstanding the recent closure of Newfoundland Refining Company Limited's 15 900 m^3 a day (100 000 b/d) refinery in Newfoundland, Canada is faced with the possibility of having a surplus of refinery capacity for several years to come due to a developing trend of decreased exports of petroleum products.

In bituminous sand development, Syncrude Canada Ltd.'s 19 875 m^3 a day (125 000 b/d) plant at Fort McMurray Alta., is now more than 50 per cent complete and is on schedule for its anticipated mid-1978 start up. Petrofina Canada Ltd., operator of a four-company group that planned a 19 398 m^3 a day (122 000 b/d) extraction plant at the Athabasca tar sands, announced its intention to shelve the project indefinitely. Petrofina gave rising costs and lack of government incentives for its action. Shell Canada Resources Limited and Home Oil Company Limited, both of which had intentions of constructing Athabasca tar sands plants, have also postponed their plans pending further economic studies.

Pilot project studies involving *in situ* methods of recovery continued both for Cold Lake- and Athabasca-type oil sands deposits and some progress was made. Hopefully some of these pilot projects will be brought into full-scale operation in the near future as over 80 per cent of the recoverable bitumen contained in the Alberta oil sands will have to be produced by these methods.

Outlook

The outlook for the Canadian oil industry is not favourable. With the possible exception of the Bent Horn discovery in the arctic islands, there has not been a major oil discovery in Canada since 1965 and crude oil reserves are declining rapidly. The potential for finding new crude oil sources in the frontier areas still exists although exploratory results have been disappointing to date. Nor has development of the Athabasca bituminous sands proceeded at the pace necessary if it is to have a significant impact on the predicted oil supply shortages of the 1980s. However, escalating crude oil prices and government incentives will likely rekindle industry interest in tar sand development during the next decade.

At Lloydminster where there are large proven reserves of heavy crude oil, it is likely that provincial and federal government incentives will speed up the development of these resources. The oil is very viscous with low recovery factors, and maximum development requires recovery techniques more advanced than those currently used in conventional oil fields, if the full potential of those resources are to be realized. In addition, the produced oil requires upgrading before it is suitable for pipeline transport and refinery use which would entail construction of a large expensive upgrading plant similar to those required for upgrading the Athabasca tar sands.

In the short-term there is no immediate danger of shortages of oil supplies in Canada; currently Canadian oil fields are producing at more than 39 747 m³ a day (250 000 b/d) below rated capacity. This shut-in capacity could compensate for any immediate shortfalls that might arise, particularly with the completion of the Sarnia-Montreal extension of the Interprovincial

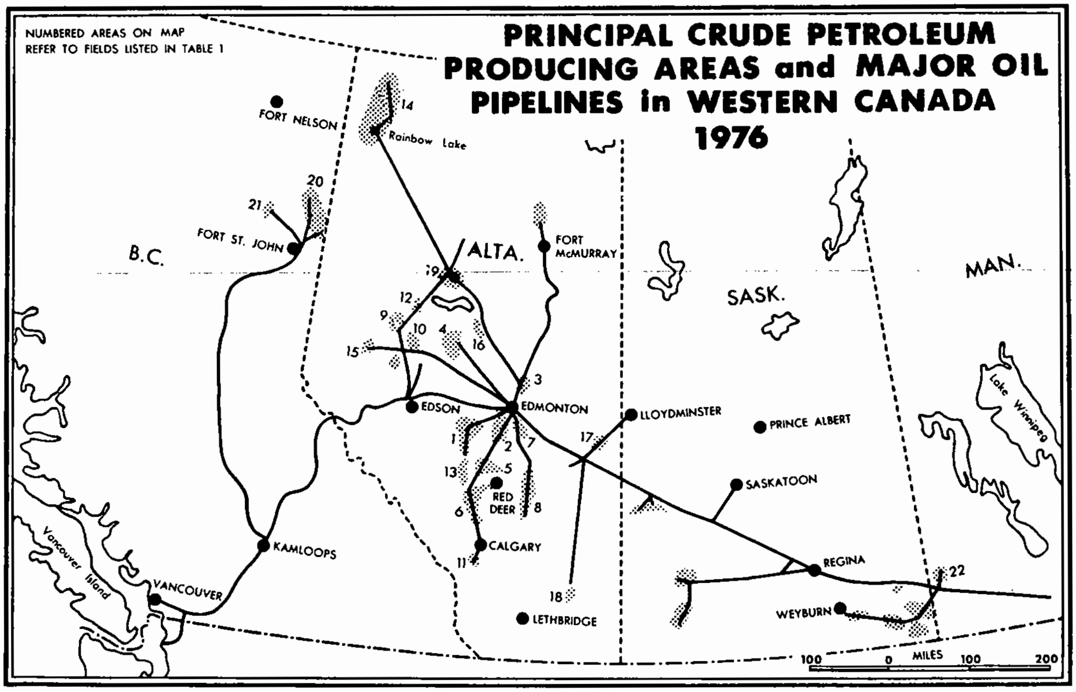


Table 1. Production of crude oil and condensate by province and field, 1975-1976
(Number in parentheses gives location of field on accompanying map)

	1975		1976^p	
	(m³)	(m³/day)	(m³)	(m³/day)
Alberta				
Swan Hills (4)	6 867 936	18 817	6 157 591	16 824
Pembina (1)	5 640 942	15 455	5 055 094	13 812
Redwater (3)	4 806 010	13 168	4 245 492	11 600
Rainbow (14)	4 649 927	12 739	4 521 066	12 352
Judy Creek	3 900 370	10 686	3 335 651	9 114
Swan Hills South (4)	3 614 032	9 901	3 410 595	9 319
Bonnie Glen (2)	3 112 006	8 526	2 613 299	7 140
Mitsue (16)	2 806 336	7 688	2 320 220	6 339
Nipisi (19)	2 471 533	6 771	2 143 082	5 855

Table 1. (cont'd)

	1975		1976^p	
	(m^3)	(m^3/day)	(m^3)	(m^3/day)
Alberta (cont'd.)				
Wizard Lake (2)	2 369 239	6 491	1 981 761	5 415
Golden Spike (2)	1 749 989	4 794	1 345 236	3 675
Fenn Big Valley (8)	1 484 942	4 068	1 313 175	3 588
Virginia Hills	1 228 220	3 365	1 053 738	2 879
Carson Creek North (4)	1 172 709	3 213	1 071 238	2 927
Leduc-Woodbend (2)	1 099 722	3 013	955 498	2 611
Sturgeon Lake South	966 192	2 647	851 649	2 327
Willesden Green (13)	847 849	2 323	815 496	2 228
Kaybob (10)	794 887	2 178	640 871	1 751
Westerose (2)	792 601	2 171	646 753	1 767
Provost	618 289	1 694	594 086	1 623
Countess	615 816	1 687	512 619	1 401
Harmattan East (6)	581 397	1 593	515 249	1 408
Innisfail (6)	547 790	1 501	411 007	1 123
Zama	526 923	1 444	483 983	1 322
Rainbow South (14)	515 999	1 414	635 326	1 736
Kaybob South (10)	485 303	1 330	615 322	1 681
Joarcam (7)	447 174	1 225	343 053	937
Medicine River (13)	439 346	1 204	428 922	1 172
Snipe Lake	432 341	1 184	443 828	1 213
Harmattan Elkton (6)	420 886	1 153	421 285	1 151
Simonette (15)	414 390	1 135	351, 660	961
Bellshill Lake	412 020	1 129	339 807	928
Wainwright (17)	389 567	1 067	410 854	1 123
Acheson (2)	378 774	1 038	603 386	1 649
Clive	371 326	1 017	396 725	1 084
Goose River	339 018	929	286 476	783
Bantry (18)	319,011	874	264 305	722
Red Earth	315 149	863	280 042	765
Virgo (14)	307 512	842	229 694	628
Grand Forks	284 732	780	337 071	921
Gilby (5)	252 059	691	264 940	724
Lloydminster	241 451	662	251 550	687
Ferrier	232 382	637	241 802	661
Sundre	228 280	625	215 369	588
Twining	228 064	624	243 825	666
Stettler	215 483	590	174 447	476
Joffre (5)	205 483	563	231 682	633
Boundary Lake South	202 840	556	192 803	527
Utikuma Lake	193 359	530	187 165	511
Meekwap	188 954	518	165 647	452
St. Albert Big Lake	184 723	506	161 354	441
Turner Valley	174 538	478	182 388	498
Cessford	172 285	472	184 855	505
Sylvan Lake	167 148	458	171 170	468
West Drumheller	166 006	455	126 575	346
Garrington	142 600	391	161 937	442
Other fields and pools	7 399 094	20 272	7 280 334	19 892
Total	70 132 954	192 145	63 820 046	174 371
Total value ($)	3 211 539 000		3 424 078 000	

Table 1. (concl'd.)

	1975		1976[p]	
	(m^3)	(m^3/day)	(m^3)	(m^3/day)
Saskatchewan[1]				
Total	9 408 551	25 777	8 912 511	24 352
Total value ($)	407 302 000		440 055 000	
British Columbia				
Boundary Lake (20)	888 136	2 433	1 100 206	3 006
Peejay	315 209	864	274 443	750
Inga (21)	255 901	701	265 358	725
Milligan Creek (20)	218 896	600	171 651	469
Weasel	143 495	393	149 749	409
Other fields and pools	464 282	1 272	424 356	1 160
Total	2 285 919	6 263	2 385 763	6 519
Total value ($)	94 917 000		116 597 000	
Manitoba				
North Virden Scallion (22)	343 472	941	303 270	828
Virden-Roselea (22)	183 859	504	161 220	441
Other fields and pools	174 439	478	169 233	462
Total	701 770	1 923	633 723	1 731
Total value ($)	31 445 000		33 441 000	
Ontario				
Total	111 927	307	98 572	269
Total value ($)	5 046 000		5 971 000	
Northwest Territories				
Total	159 941	438	142 453	389
Total value ($)	4 537 000		4 041 000	
New Brunswick				
Total	1 113	3	477	1
Total value ($)	51 000		24 000	
Canada				
Total	82 802 175	226 856	75 993 545	207 633
Total value ($)	3 754 837 000		4 024 207 000	

Sources: Provincial government reports and Statistics Canada.
[1]Saskatchewan lists production by formation rather than by field.
[p]Preliminary.

pipeline system. Production of crude oil and equivalent (includes condensate and pentanes plus) will likely increase by about 24 645 m^3 a day (15 000 b/d) to 253 300 m^3 a day (1 592 000 b/d) in 1977. All of this increase in demand will be accounted for by domestic markets as Montreal refiners are expected to take the rated maximum throughput of 39 747 m^3 a day (250 000 b/d) of the Sarnia-Montreal pipeline. In addition, the Petrosar complex at Sarnia is expected to go on stream by mid-summer, adding an average of 12 720 m^3 a day (80 000 b/d) capacity to serve Ontario's current demand. Elsewhere in Canada, consumption of petroleum products likely will not increase over 1976 because of increased prices and conservation programs. Exports of crude oil and equivalent will decrease to 49 124 m^3 a day (309 000 b/d), and probably less, as Canada continues to phase out exports within the time frames laid down by the National Energy Board (NEB).

Reserves

At the end of 1976 Canada's proven liquid hydrocarbon reserves, which include conventional crude oil and natural gas liquids, amounted to 1.24 billion m^3 (7.8 billion barrels). This is comprised of 1.0 billion m^3 (6.3 billion barrels) of crude oil and .246 billion m^3 (1.5 billion barrels) of natural gas liquids. These estimates do not include oil in the Athabasca bituminous sands. At the 1976 annual production level of 92.6 million m^3 (583 million barrels) the life index (reserves-to-production ratio) for conventional crude oil and natural gas liquids rose from 13.2 years to 13.8 years. The rise is not because of an increase in proven reserves, but rather because of reduced producing rates.

The reserve position of most provinces declined, the most notable reduction occurring in Alberta where total reserves including natural gas liquids dropped by 66 million m^3 (415 million barrels). The Canadian Petroleum Association (CPA) estimated Alberta's remaining recoverable reserves of crude oil at .86 billion m^3 (5.39 billion barrels) and natural gas liquids at .23 billion m^3 (1.46 billion barrels). Together these accounted for about 88 per cent of Canada's proven reserves. Saskatchewan's reserves of liquid hydrocarbons declined from .108 billion m^3 (680 million barrels) to .104 billion m^3 (653 million barrels in 1976 and accounted for 8.4 per cent of the national total.

Natural gas liquids from the recently discovered,

Table 2. Production of natural gas liquids by province, 1975-76

	1975		1976[p]	
	(000 m^3)	(m^3/day)	(000 m^3)	(m^3/day)
Alberta				
Propane	5 367	14 705	5 249	14 341
Butane	3 506	9 605	3 440	9 399
Pentanes plus	8 448	23 144	7 432	20 306
Condensate	115	316	123	336
Total	17 436	47 770	16 244	44 382
Saskatchewan				
Propane	89	244	81	222
Butane	38	104	37	101
Pentanes plus	27	75	24	66
Condensate	25	68	23	62
Total	179	491	165	451
British Columbia				
Propane	82	224	88	241
Butane	106	292	110	300
Pentanes plus	185	508	168	458
Condensate	16	44	18	50
Total	389	1 068	384	1 049
Canada				
Propane	5 538	15 173	5 418	14 804
Butane	3 650	10 001	3 587	9 800
Pentanes plus	8 660	23 727	7 624	20 830
Condensate	156	428	164	448
Total	18 004	49 329	16 793	45 882
Returned to formation	14	38	7	18
Total net production	17 990	49 291	16 786	45 864

Source: Provincial government reports.
[p] Preliminary.

but as yet unproduced, gas fields in the Mackenzie Delta are included in the estimates but oil from the frontier regions is not. This is because discovered reserves of crude oil in the Territories are negligible and currently well beyond economic reach.

Commencing in 1975 the CPA adopted new procedures for estimating oil sands reserves. Synthetic crude oil reserves associated with each plant are calculated on the basis of the plant's rated output capacity over a 25-year period; the 25 years being indicative of a reasonable economic life for the facilities. New projects are recognized by the CPA three years prior to the scheduled start-up date of each such project. Based on this method, the CPA estimates the remaining proved developed non-conventional crude oil reserves at the end of 1975 at .238 billion m^3 (1.5 billion barrels). These estimates are not to be confused with published estimates of approximately 10 to 26.5 billion m^3 (67 to 167 billion barrels) believed to be recoverable from Athabasca-type oil sands by mining or *in situ* processes.

Production

Average production of crude oil, including synthetic oil and natural gas liquids, totalled 253 046 m^3 a day (1.59 million barrels a day) — 8 per cent or 22 668 m^3 a day (142 577 b/d) less than in 1975. Crude oil production, including synthetic crude oil, declined by 19 233 m^3 a day (121 000 b/d) to 207 218 m^3 a day (1 303 149 b/d). Synthetic crude oil output was 7 519 m^3 a day (47 300 b/d), up 536 m^3 a day (4 300 b/d) from 1975. Natural gas liquid production decreased by 3427 m^3 a day (21 500 b/d) to 45 864 m^3 a day (288 000 b/d), consisting of 21 278 m^3 a day (134 000 b/d) of pentanes plus and condensate and 24 604 m^3 a day (154 000 b/d) of propane and butane. Alberta's crude oil production declined by 18 000 m^3 a day (112 000 b/d) and accounted for 84 per cent of total Canadian output. Saskatchewan's crude oil production of 24 352 m^3 a day (153 000 b/d) was down 1425 m^3 a day (9 000 b/d) from 1975 production levels and accounted for 12 per cent of the Canadian total. British Columbia's production increased to 6519 m^3 a day (41 000 b/d), 256 m^3 a day (600 b/d) more than in 1975 and accounted for 3.0 per cent of total national production. Manitoba accounted for 0.8 per cent and Ontario and the Northwest Territories together, 0.2 per cent. All provinces except Alberta and Saskatchewan were producing at capacity.

In the Athabasca tar sands area, the Great Canadian Oil Sands Limited oil extraction plant, the only one yet completed, had the most successful year since it commenced operating. Production averaged over 7519 m^3 a day (47 300 b/d). The $2 billion oil sands plant being built by Syncrude Canada Ltd. is 52 per cent complete and construction expenses are no more than anticipated. The 19 875-m^3-a-day (125 000 b/d) plant is scheduled to begin operating in mid-1978 and the successful construction of this plant is likely to revive interest amongst those companies which have recently shelved plans to proceed with tar sands development. Improving economics, largely as a result of increasing crude oil prices, and possible incentives of reduced royalty and tax payments, will likely speed up tar sand development in the next decade. It is becoming increasingly apparent that if Canada intends to reduce its dependence on imported oil in the 1980s, the Athabasca tar sands is a prime starting point. To this end, meetings between the federal and provincial governments regarding future development of bituminous sands commenced late in 1976. The thrust of these meetings was that development of these large sources of crude oil must be speeded up.

Table 3. Value of natural gas liquids, 1975-76

	1975	1976^p
	($ 000)	
Alberta	760 501	772 414
Saskatchewan	6,381	5,787
British Columbia	15,455	16,124
Total	782,337	794,325
Volume (000 m^3)	17,834	16,543

Source: Statistics Canada.
^{p}Preliminary.

Discussions aimed at building a heavy crude upgrading facility in the Lloydminster area are currently taking place between the Saskatchewan government, the federal government and company officials. The discussions centre on the construction — on the Saskatchewan side of Lloydminster — of one large upgrading plant which could be used on a public-utility basis by heavy oil producers in the area. The discussions are the result of the federal government's policy to use domestically as much of Canada's oil as possible. To do this, the large reserves in the Lloydminster area must either be refined there or upgraded so they can be transported in pipelines to eastern Canada refineries. It would seem that the latter of these two alternatives is the most practical. No cost studies have yet been prepared on building an upgrading facility but preliminary estimates place the costs between $250 million and $1 billion, depending on the size.

Exploration and Development

Alberta. Encouraged by escalating crude oil and natural gas prices, plus drilling incentives, the number of wells completed in 1976 was more than 30 per cent greater than in 1975. Total number of wells drilled in all categories amounted to 5042 for a total length of 4.87 million metres (15.98 million feet). This is 1.22 million metres (4.0 million feet) more than was drilled in 1975. Both development and exploratory drilling increased and, as in 1975, most of the exploratory drilling was directed towards the finding of new gas supplies.

Again there were several oil discoveries in Alberta but most of them appear to be of little substance. Among the most significant were the heavy-oil discoveries made in the Suffield Block of southeastern Alberta. By year-end 11 successful oil completions had been made in this area since the "deep rights" program commenced in 1976. In addition, several gas discoveries have also been made in conjunction with the oil discoveries, all in Cretaceous formations. It should be recalled that 76 464 million cubic metres (2.7 tcf) of proven reserves of gas were discovered in a shallower horizon in the Suffield Block by an Alberta-government-sponsored drilling program. Further exploratory and development drilling is contemplated in 1977 to determine the extent of these new discoveries in terms of productivity and reserves.

In the Chigwell area of central Alberta several oil discoveries were made during 1976. The producing zones are reported to be in the Viking and Nisku formations. Although it is too early to determine the significance of the discoveries, early indications are that they are not large.

Most of the development drilling was confined to the heavy oil belt in the Wainwright and Lloydminster areas, despite continuing problems in marketing this type of crude oil. The remainder of the development drilling was done to improve the productivity and recovery of known fields. The largest development drilling projects occurred in the Willesden Green, Rainbow Lake and Cessford fields.

In the field of enhanced recovery there was little to report in 1976. Most of the oil fields in Alberta that are amenable to secondary recovery schemes are already using them; primarily, waterflood. However, there are 3.8 billion m^3 (24 billion barrels) of oil in Alberta that are known to exist but are considered to be unrecoverable under present circumstances. In this connection, the Alberta government in conjunction with federal authorities will fund a major research program dealing with more sophisticated enhanced recovery techniques than those currently available. It is anticipated that through improved technology and economics, a significant volume of currently unrecoverable oil in place will eventually be produced.

Interest was maintained in developing Alberta's vast resources of heavy oil in the Cold Lake area of eastern Alberta despite a decided downturn in market demand for heavy crude oil in Canada and the United States. Imperial Oil Limited has been one of the pioneers in Cold Lake oil sands development and has spent about $40 million since 1964 experimenting with potential extraction methods. Currently, the company is operating a 56-well, steam-injection project. Anticipated production from the pilot project is 794 m^3 a day (5000 b/d) which will be shipped to Imperial's new Strathcona refinery in Edmonton as feedstock for asphalt. Depending on technical success in the pilot stage, Imperial eventually intends to expand this project into a full-scale operation with an ultimate production level of 15 898 m^3 a day (100 000 b/d).

Saskatchewan and Manitoba. Although activity in Saskatchewan continued at a subdued pace in 1976, both exploratory and development drilling were up slightly from 1975. Total amount drilled was 229 670 metres (753 513 feet) compared to 197 878 metres (649 205 feet) in 1975. Wells drilled numbered 257 compared to 267 in the previous year, which is indica-

Table 4. Canada, crude oil production, trade and refinery receipts, 1966-76

	Production	Imports[1]	Exports[1]	Refinery Receipts[2] Domestic	Refinery Receipts[2] Imports	Refinery Receipts[2] Totals
			(m^3)			
1966	50 962 233	23 224 372	19 665 353	35 008 467	24 206 931	60 215 398
1967	55 851 019	27 152 643	23 902 877	35 703 749	25 938 587	61 642 336
1968	60 319 190	28 258 178	26 628 460	37 549 362	28 187 357	65 736 719
1969	65 342 179	30 704 398	31 374 672	38 480 450	30 283 755	68 764 205
1970	73 321 772	33 011 020	38 299 028	41 172 360	33 123 391	74 295 751
1971	78 339 251	38 947 402	43 049 070	41 851 685	38 828 645	80 680 330
1972	89 347 195	44 781 024	54 254 874	43 441 393	45 908 256	89 349 649
1973	104 272 315	52 056 975	66 784 203	47 715 892	49 491 498	97 207 390
1974	97 741 735	46 290 090	53 015 317	55 249 631	47 582 182	102 831 813
1975	82 802 176	47 415 986	41 727 024	50 963 152	47 776 787	98 739 939
1976[p]	75 993 545	43 951 365	29 044 085	56 482 764	41 854 972	98 337 736

Source: Statistics Canada.
[1]Trade of Canada (SC) date. [2]Includes condensate and pentanes plus.
[p]Preliminary.

Table 5. Canada, year-end reserves of crude oil, 1975-1976

	1976	% of Total 1975	% of Total 1976	Net change 1976 over 1975
	(000 m³)			
Alberta	857 098	86.4	86.2	−56,908
Saskatchewan	102 598	10.1	10.3	− 4,194
British Columbia	21 510	2.2	2.2	− 1,779
Northwest Territories	6 156	0.6	0.6	− 171
Manitoba	5 811	0.6	0.6	+ 7
Eastern Canada	1 624	0.1	0.1	+ 99
Total	994 797	100.0	100.0	-62,946

Source: Canadian Petroleum Association.

Table 6. Canada, reserves of liquid hydrocarbons at end of 1976

	Natural Gas Liquids	Crude Oil Plus Natural Gas Liquids	% of Total
	(000 m³)		
Alberta	232 536	1 089 634	87.8
Saskatchewan	1 231	103 829	8.4
British Columbia	6 540	28 051	2.3
Other areas	5 504	19 094	1.5
Total	245 811	1 240 608	100.0

Source: Canadian Petroleum Association.
— Nil.

tive of industry decisions to explore deeper horizons than in previous years. As in 1975, a number of these were drilled by the Saskatchewan Oil and Gas Corporation (Saskoil), the provincial crown corporation. In 1975 an oil discovery at Tableland in southeastern Saskatchewan was considered significant because it was made in the Winnipegosis formation, a deeper horizon than that from which the bulk of Saskatchewan's current production is obtained. However, the results of offset drilling in 1976 would seem to indicate the field is small and only marginally economic.

In Manitoba the number of wells and metres drilled increased in 1976. Aggregate drilling amounted to 13 515 metres (44 341 feet) and 16 wells were drilled. Some infill drilling was done in the Virden and Daly fields during the year but no new oil discoveries were made.

British Columbia. Encouraged by higher gas prices and reduced royalties, both development and exploratory drilling increased substantially in 1976. Exploratory drilling at 147 966 metres (485 456 feet) was up 63 349 metres (207 838 feet) from 1975. Development drilling increased by 91 254 metres (299 391 feet) to 135 124 metres (443 320 feet). Although there were several gas discoveries recorded in British Columbia, there were no oil discoveries and almost all of the development drilling was confined to natural gas fields.

Yukon Territory, Northwest Territories and Arctic islands. In the territorial regions exploration fell off considerably in 1976 and there was a lower success ratio. Twenty-seven wells were drilled for a total of 83 807 metres (274 957 feet) compared to 43 wells and 113 218 metres (371 450 feet) in 1975. Some significant discoveries were made this year despite the decline in drilling.

In the Mackenzie Delta, Gulf Oil Canada Limited drilled several successful gas discoveries in the Parson's Lake area and considerably extended the as-yet-undefined limits of the field. The final well in a six-well drilling program in the 1975-76 winter drilling season, Gulf-Parsons D-20, was drilled directionally under the lake to a total depth of 4115 metres (13 500 feet) and tested gas from .48 to .58 million cubic metres per day (17 to 20.5 mmcf/d). The drilling program produced five gas wells and an oil discovery at the Kamik D-48 well which is located on a different structure than the main Parson's Lake gas field a few kilometres to the west. The Kamik well flowed oil at rates up to 445 m³ a day (2800 barrels) per day, but Gulf says further drilling will be necessary to establish its significance. Three locations in the area are currently being prepared for the 1976-77 drilling season.

Offshore in the Beaufort Sea Dome Petroleum Limited commenced its multi-well drilling program this year utilizing three specially designed, ice-reinforced drill ships. The discovery well, Dome Gulf *et al* Tingmiark K-91, 56 km (35 miles) offshore was drilled to the 2987-metre (9800-foot) level where natural gas was encountered. Adhering to a federal decree, Dome suspended drilling at the well before the gas-bearing zone could be fully evaluated and before it could be determined if there was an oil leg associated with the gas. In the interests of the environment and safety, the federal government had previously directed that all 1976 Beaufort Sea drilling must be completed by September 25, 1976. The well will be completed and evaluated during the 1977 summer drilling season. Depending on pay zone thickness and producibility, the discovery may be significant as it is located on a large seismically outlined structure. Surface casing was installed during 1976 for two more Beaufort sea wells which will also be drilled during the summer of 1977. Depending on timing, four additional wells could be drilled before the end of the 1977 drilling season.

In the arctic islands, Panarctic Oils Ltd. made two significant gas discoveries in April 1976. The first was a major northwestward extension to the Hecla gas field off the Sabine Peninsula, Melville Island. The well was drilled 24 km (15 miles) offshore in 30 metres (100 feet) of water from an artificially thickened ice pad. The Hecla field is now over 40 km (25 miles) long and is estimated to contain upwards of 99 108 million m^3 (3.5 tcf) of natural gas. The second gas discovery called Jackson Bay was drilled four kilometres offshore from Ellef Ringnes Island in 60 metres (200 feet) of water about midway between Panarctic's King Christian Island gas field and the gas field at Kristoffer Bay on Ellef Ringnes Island. The well was drilled on a separate structure from those of the two previous discoveries in the area and is reported to have a net pay of 177 metres (583 feet) and high reservoir pressures.

On Cameron Island in the Arctic, Panarctic's Bent Horn A-02 well, drilled as a follow-up to its previous oil discovery, has produced significant quantities of crude oil on preliminary test. This latest step-out well encountered the producing zone 365 metres (1200 feet) higher than a well drilled previously, about 1 kilometre southwest, and yielded 445 m^3 (2800 b/d) on a drill steam test. Unofficial estimates place the recoverable reserves of the Bent Horn Field at 16 to 32 million m^3 (100 to 200 million barrels) which may be adequate for commercial development. The operator is currently studying the feasibility of transporting this oil via a proposed pipeline to the southern tip of Bathurst Island

Table 7. Canada, wells completed and footage drilled

	1955		1960		1975		1976^p	
	(no.)	(m)	(no.)	(m)	(no.)	(m)	(no.)	(m)
Western Canada								
Westcoast offshore								
New field wildcats	—	—	—	—	—	—	—	—
British Columbia								
New field wildcats	34	59 135	60	111 501	12	29 656	6	16 305
Other exploratory	2	3 969	11	16 992	35	54 962	77	131 662
Development	—	—	72	101 115	33	43 870	92	135 124
	36	63 104	143	229 608	80	128 488	175	283 091
Alberta								
New field wildcats	307	540 709	338	663 641	350	413 714	336	475 244
Other exploratory	105	133 180	223	356 945	847	1 043 549	1 235	1 489 092
Development	1 208	1 895 798	1 131	2 171 961	2 449	2 191 907	3 471	2 907 372
	1 620	2 569 687	1 692	3 192 547	3 646	3 649 170	5 042	4 871 708
Saskatchewan								
New field wildcats	312	360 495	113	142 801	55	47 788	51	56 876
Other exploratory	50	54 715	28	30 237	52	41 442	89	73 650
Development	550	570 903	461	547 411	160	108 648	117	99 144
	912	986 113	602	720 449	267	197 878	257	229 670
Manitoba								
New field wildcats	59	53 131	10	9 298	4	3 628	10	7 400
Other exploratory	10	7 236	3	1 942	—	—	3	3 011
Development	292	197 321	54	33 550	3	3 059	3	3 103
	361	257 688	67	44 790	7	6 687	16	13 515
Yukon and Northwest Territories and Arctic Islands								
New field wildcats	6	3 739	32	32 299	30	78 805	20	56 569
Other exploratory	—	—	—	—	2	7 569	2	3 885
Development	—	—	—	—	10	26 844	9	25 700
	6	3 739	32	32 299	42	113 218	31	86 154
Total western Canada								
New field wildcats	718	1 017 209	553	959 540	452	573 591	423	612 394
Other exploratory	167	199 100	265	406 116	936	1 147 522	1 406	1 701 300
Development	2 050	2 664 022	1 718	2 854 037	2 655	2 374 328	3 692	3 170 444
	2 935	3 880 331	2 536	4 219 693	4 041	4 095 441	5 521	5 484 138

Table 7. (concl'd.)

	1955		1960		1975		1976[p]	
	(no.)	(m)	(no.)	(m)	(no.)	(m)	(no.)	(m)
Eastern Canada								
Eastcoast offshore								
New field wildcats	—	—	—	—	10	32 753	11	22 793
Other exploratory	—	—	—	—	—	—	—	—
	—	—	—	—	10	32 753	11	31 787
Hudson's Bay offshore								
New field wildcats	—	—	—	—	—	—	—	—
Other exploratory	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—
Ontario								
New field widlcats	64	34 213	39	20 846	49	28 788	40	26 459
Other exploratory	57	28 205	55	33 479	16	8 302	15	8 862
Development	266	82 659	213	69 552	73	28 611	89	37 951
	387	145 077	307	123 877	138	65 701	144	73 272
Quebec								
New field wildcats	9	3 117	5	1 307	3	3 037	4	8 543
Other exploratory	—	—	—	—	—	—	—	—
Development	—	—	1	73	—	—	—	—
	9	3 117	6	1 380	3	3 307	4	8 543
Atlantic provinces								
New field wildcats	2	1 462	3	6 969	7	17 134	2	3 271
Other exploratory	—	—	—	—	—	—	—	—
Development	7	6 444	—	—	—	—	—	—
	9	7 906	3	6 969	7	17 134	2	3 271
Total Eastern Canada								
New field wildcats	75	38 791	41	29 122	69	81 712	57	70 060
Other exploratory	57	28 205	55	33 479	16	8 302	15	8 862
Development	273	89 103	214	69 625	73	28 611	89	37 951
	405	156 099	316	132 226	158	118 605	161	116 873
Total Canada								
New field wildcats	793	1 056 000	600	988 662	521	655 303	490	619 454
Other exploratory	224	227 305	320	439 595	952	1 155 824	1 421	1 710 162
Development	2 323	2 753 125	1 932	2 923 662	2 728	2 402 939	3 781	3 208 395
	3 340	4 036 430	2 852	4 351 919	4 201	4 214 066	5 692	5 538 011

Source: Canadian Petroleum Association.
[p]Preliminary; — Nil.

from where it would be transported by ice-breaking tanker to southern markets.

In November of 1976 Sun Oil Company Limited and Global Arctic Islands Limited announced a farm-out agreement with a four-company group composed of Imperial Oil Limited, Gulf Oil Canada Limited, Panarctic Oils Ltd. and Petro-Canada Exploration Inc. Under terms of the agreement the four-company group agreed to spend $80 million on exploration in return for a working interest in 1 335 444 million m^2 (33 million acres) of Sun Oil's permit acreage in the arctic islands.

Eastern Canada. Aggregate drilling in Ontario increased in 1976 by 5 per cent to 73 272 metres (240 395 feet). Exploratory drilling accounted for 48 per cent of the total, down 2 per cent from the previous year. Development drilling also increased from the previous year as 89 wells and 37 951 metres (124 512 feet) were drilled. Both exploration and development drilling decreased slightly onshore but increased substantially in Lake Erie. Although the discoveries are generally small fields, exploration companies are being encouraged by a relatively high success ratio, higher gas and oil prices, and comparatively cheap underground storage.

Lake Huron and Lake St. Clair continue to remain under control of the Great Lakes Water Quality Agreement and International Joint Commission, and the environmental studies being conducted have closed off the lakes to all exploration. The lakes have prime pinnacle and patch reef targets, while the Devonian potential provides an added inducement.

In Quebec four wells were drilled and all were exploratory. None were successful oilwells.

Offshore from the east coast the number of wells increased but metres drilled declined slightly in 1976. Ten wells were drilled for a total of 22 793 metres (74 780 feet) compared with nine wells and 26 314 metres (86 330 feet) in 1975. All wells were in the exploratory category.

Drilling commenced offshore from the east coast in 1966 and since then 136 wells have been drilled, from which seven, and probably eight, oil and gas discoveries have been made. The two most important of these were made in 1973 and 1974 on the Labrador Shelf. The Bjarni-H81 well, drilled in 1973, and the Gudrid well, drilled in 1974, turned out to be significant discoveries. Two more potential gas discoveries were made on the Labrador Shelf in 1975. Both had to be suspended because of weather and the short drilling season. Both were reentered, drilled to total depth and evaluated in 1976. One of these, Eastcan Snorri J-90, located about 1126 km (700 miles) north of St. John's, Newfoundland, yielded significant flows of gas and condensate and is considered to be a potential commercial discovery. The other well, Karlsefni H-13, also penetrated a gas- and condensate-bearing reservoir but is not considered to be commercial at the present time.

On the Grand Banks and Scotian Shelf exploration has been declining, as results have been costly and disappointing. The only discoveries in this region have been made in the vicinity of Sable Island where the initial discovery was made in 1971 on the southwestern tip of the island. About 9.6 km (six miles) to the southwest, a gas condensate discovery was made a year later and the third significant gas discovery was made 48 km (30 miles) east of Sable Island when the Primrose N-50 well gave flows of gas with condensate

Table 8. Wells drilled, by province, 1975-76

	Oil		Gas		Dry[1]		Total	
	1975	1976[p]	1975	1976[p]	1975	1976[p]	1975	1976[p]
Western Canada								
Alberta	660	550	1 922	3 193	1 064	1 229	3 646	5 042
Saskatchewan	105	154	85	16	77	87	267	257
British Columbia	2	13	31	86	47	76	80	175
Manitoba	2	3	—	—	5	13	7	16
Yukon and Northwest Territories & Arctic islands	3	4	6	9	34	18	43	31
Westcoast offshore	—	—	—	—	—	—	—	—
Subtotal	772	724	2 044	3 304	1 227	1 423	4 043	5 521
Eastern Canada								
Ontario	4	3	68	67	66	74	138	144
Quebec	—	—	—	2	3	2	3	4
Atlantic provinces	—	—	—	—	7	2	7	2
Eastcoast offshore	—	—	—	—	9	11	9	11
Hudson's Bay offshore	—	—	—	—	—	—	—	—
Subtotal	4	3	68	69	85	89	157	161
Total Canada	776	727	2 112	3 373	1 312	1 512	4 200	5 682

Source: Canadian Petroleum Association.
[1] Includes suspended and abandoned wells, but excludes miscellaneous wells.
[p] Preliminary; — Nil.

from three separate zones. The other find was an oil discovery — the Cohasset D-42 well — located 40 km (25 miles) southwest of Sable Island.

In 1976 exploration on the Scotian Shelf was revitalized to some degree by Petro-Canada when it embarked on a multi-well drilling program which commenced early in the year. The program involves three separate exploration agreements with major oil companies which have been active in the east offshore area for several years. Cost of the Petro-Canada program is in the order of $20 million. Of the initial six wells drilled, only one, Shell-Petro-Canada-Penobscot B-41 located 32 km (20 miles) north of Sable Island, showed any promise. Shell, the operator, announced that several non-commercial oil zones were encountered. As a result, a follow-up well has been licenced by the Shell-Petrocan team, and should this well prove to be successful it is anticipated a new drilling agreement will be formulated between the partners to delineate the structure and others in the vicinity.

In addition to its current $20 million drilling project on the Scotian Shelf with Shell the company is engaged in another $24 to $48 million venture on Sable Island with Mobil Oil Canada, Ltd., Texas Eastern Exploration of Canada Ltd. and Texaco Exploration Canada Ltd. While the prospects on the Scotian Shelf do not appear to be significant on a world-scale basis, according to Petro-Canada officials they appear to be sufficiently large to provide an important local supply for the Maritimes and enable them to reduce their dependence on imported oil.

Transportation

Pipeline construction at 872 km (542 miles) increased in 1976 largely due to the completion of the Sarnia-Montreal extension of the Interprovincial system. Other than this, pipeline construction continued the decline that commenced in 1973. The lack of new oil discoveries and regulated cutbacks in crude oil production were responsible for this decrease.

Interprovincial Pipe Line Limited's 762-mm (30-inch) oil pipeline from Sarnia to Montreal was completed in June 1976 and was the only large-diameter project finished during the year. The line will eventually have a capacity of 55 643 m^3 a day (350 000 b/d) and initial throughput is 39 745 m^3 a day (250 000 b/d). Fully powered with 16 pumping stations, the capacity of the line would approach 109 696 m^3 a day (690 000 b/d) if necessary, and flow in the line can be reversed.

In product pipelines, construction commenced on the 321-km, 304-mm (200-mile, 12-inch) $300 million natural gas liquids pipeline from Edmonton, Alberta to Sarnia, Ontario via the United States. After receiving a certificate from the National Energy Board for approval of ethylene and ethane exports to the United States, Dome Petroleum Limited, one of the principals in the system, announced that work would commence on 12 river crossings in 1976. The 11 925 m^3 (75 000 b/d) project has been planned for more than five years and is due to be completed early in 1978. The Canadian portions of the system are called the Cochin pipeline and the United States segment will be known as the Dome segment. The system primarily will carry ethane, ethylene, and propane from plants near Edmonton and Red Deer, Alberta, crossing the border near Sherwood, North Dakota, and again at Windsor, Ontario. A spur line will supply Columbia Gas System Inc's synthetic natural gas plant at Green Springs, Ohio, with 6360 m^3 (40 000 b/d) of gas liquids.

In Ontario Trans-Northern Pipe Line Company reportedly has completed looping a 22-km (14-mile) stretch of its products pipeline south of Ottawa. In addition, it is planning to reactivate two pumping stations to provide the capacity to move more products from Toronto area refineries to the Ottawa market.

Table 9. Oil wells in western Canada at end of 1975-76

	Producing Wells		Wells Capable of Production	
	1975	1976	1975	1976
Alberta	10 708	11 166	15 177	15 663
Saskatchewan	6 073	5 938	7 675	7 768
Manitoba	657	669	844	797
British Columbia	459	522	696	702
Northwest Territories and Arctic Islands	37	33	59	59
Total	17 934	18 328	24 451	24 989

Sources: Provincial and federal government reports.

Table 10. Kilometres in Canada of pipelines for crude oil, natural gas liquids and products

Year-end	Kilometres	Year-end	Kilometres[1]
1960	13 576	1968	23 870
1961	15 376	1969	27 480
1962	16 153	1970	27 459
1963	17 070	1971	28 706
1964	18 900	1972	29 467
1965	19 819	1973	30 146
1966	20 913	1974	31 262
1967	22 780	1975	31 831
		1976[p]	32 703

Source: Statistics Canada.
[1] Includes producer gathering lines for 1969 to 1976.
[p] Preliminary.

Future major oil pipeline proposals include that of Kitimat Pipe Line Ltd. Kitimat applied to the National Energy Board on December 8 for approval of its plan to build and operate a new 1211-km (753-mile), $494 million, oil pipeline from Kitimat, British Columbia to Edmonton. A group of six companies would form the new firm and participate in the project: Ashland Oil Canada Limited, Farmers Union Central Exchange, Incorporated; Hudson's Bay Oil and Gas Company Limited, Interprovincial Pipe Line Limited, Koch Industries, Inc.; and Murphy Oil Corporation. If approved, the pipeline will carry crude oil brought to Kitimat by tanker from Alaska and sources in the Middle East and Indonesia.

In October of 1976 the Alberta Oil Sands Pipeline Ltd. received approval from the Alberta Energy Resources Conservation Board (AERCB) to construct an oil line for the transmission of synthetic crude oil from the Mildred Lake extraction plant of Syncrude Canada Ltd. to the Interprovincial Pipe Line Limited terminal in Edmonton. The proposed line will comprise some 434 km of 583-mm pipe and 11 km of 532-mm (270 miles of 22-inch pipe and 7 miles of 20-inch pipe) with four pump stations along the route. Timing of completion of the line will coincide with the start-up of the Syncrude plant which is currently scheduled for 1978.

Table 11. Deliveries of crude oil and propane by company and destination, 1975-76

Company and destination	1975	1976
	(millions of cubic metres)	
Interprovincial Pipeline Line		
Western Canada	8.0	7.2
United States	29.7	26.5
Montreal, Quebec	—	4.8
Ontario	29.6	30.3
Total	67.3	68.8
Trans Mountain Pipe Line		
British Columbia	7.1	7.4
State of Washington	10.4	5.8
Westridge terminal	0.7	0.5
Total	18.2	13.7

Sources: Company annual reports.
— Nil.

Petroleum refineries

Canadian refinery capacity increased by 26 279 cubic metres per day (165 300 b/d) in 1976 to 357 434 m^3 a day (2 248 300 b/d), primarily reflecting major expansions of Irving Oil Limited's refinery in Saint John, New Brunswick and Chevron Canada Limited refinery in Burnaby, British Columbia. Other refinery growth was restricted to minor additions to existing plants. The number of refineries operating in Canada was reduced to 37 at the end of 1976 as one refinery in western Canada was shut down.

In the Atlantic Provinces, Irving Oil Limited completed the expansion of its Saint John refinery by mid-1976. The capacity of the plant was increased to 39 750 m^3 a day (250 000 b/d) from its former operating level of 19 080 m^3 a day (120 000 b/d) making it the largest in Canada. Newfoundland Refining Company Limited's Come-By-Chance 15 900 m^3 a day (100 000 b/d) refinery in Newfoundland has temporarily suspended operations because of financial problems.

In Quebec, Imperial Oil Enterprises Ltd. finished the $40 million modernization of its Montreal refinery by mid-1976, while Shell Canada Limited completed the installation of a 3180 m^3 a day (20 000 b/d) reformer at its Montreal East refinery. Capacity growth at other refineries was negligible.

Refinery growth in Ontario was relatively minor in 1976, essentially being confined to a 795 m^3 a day (5000 b/d) increase in the capacity of Sunoco Inc.'s Sarnia plant. However, anticipated future refinery growth in Ontario is substantial as two major refineries, currently under construction, are nearing completion. Construction of Texaco Canada Limited's 15 103 m^3 a day (95 000 b/d) Nanticoke plant on the north shore of Lake Erie is proceeding on schedule and the plant should be completed by the end of 1977 or early in 1978. Currently the largest refinery complex under construction in Ontario is Petrosar Limited's petrochemical refinery in Sarnia. The Petrosar facility is scheduled to come on stream in 1977 and when fully operational will produce about 18 283 m^3 a day (115 000 b/d) of refined petroleum products, including motor gasoline, home heating and residual oils.

On the Prairies the most significant event in refinery development was the official start-up of Imperial's 22 530 m^3 a day (141 700 b/d) Edmonton refinery. The extra 15 900 m^3 a day (100 000 b/d) throughput allowed the company to phase out crude distillation units at Regina, Calgary and Winnipeg. Rationalization of western Canadian refinery operations continued when Husky Oil Ltd. purchased all of Union Oil Company of Canada Limited's refinery and marketing operations. The purchase included Union's 1224 m^3 a day (7700 b/d) refinery at Prince George, British Columbia. In Saskatchewan, Canada's smallest refinery, the 191 m^3 a day (1200 b/d) plant of Canadian Propane Gas & Oil Ltd. at Kamsack was closed on October 1 after more than 40 years of operations. The decision was made following prolonged labour-management problems that could not be resolved. Elsewhere in Saskatchewan Gulf Oil Canada Limited completed the 636 m^3 a day (4000 b/d) expansion of its Moose Jaw refinery. Two proposed plants in Alberta: Turbo Resources Limited's 15 898 m^3 a day (100 000 b/d)

Table 12. Crude oil refining capacity by regions

	1975		1976	
	m^3/day	(%)	m^3/day	(%)
Atlantic provinces	66 107	20.0	86 807	24.3
Quebec	102 403	30.9	102 674	28.7
Ontario	85 901	25.9	87 379	24.5
Prairies and Northwest Territories	52 895	16.0	54 056	15.1
British Columbia	23 864	7.2	26 535	7.4
Total	331 170	100.0	357 451	100.0

Source: Department of Energy, Mines and Resources, *Petroleum Refineries in Canada* (Operators List 5), January 1977.

refinery near Edmonton, which planned to use condensate and waste oils to produce mainly gasoline and diesel fuels; and Husky Oil Ltd.'s 5565 m^3 a day (35 000 b/d) plant at Lloydminster, which would have used heavy crude oils as a feedstock to produce a full range of products; have been deferred pending clarification of feedstock supplies in the case of Turbo, and marketing and technological concerns on the part of Husky.

In British Columbia Chevron Standard Limited has completed the $50 million expansion program at its Burnaby plant, more than doubling current capacity to 7155 m^3 a day (45 000 b/d). The British Columbia Petroleum Corporation, a provincial crown corporation, has decided not to proceed with a proposed new 13 515 m^3 a day (85 000 b/d) refinery, conceding that anticipated market growth for petroleum products did not warrant its construction at this time.

Marketing and trade

Receipts of crude oil and equivalent at Canadian refineries totalled 268 682 m^3 a day (1.69 million barrels daily) in 1976, 1 per cent less than in 1975. Deliveries of domestic crude oil to Canadian refiners increased by 15 080 m^3 a day (95 000 b/d), or 11 per cent. Almost all of this increase can be accounted for by the delivery of 13 197 m^3 a day (83 000 b/d) of western Canadian crude oil to Montreal refineries. These shipments began during the latter half of 1976, and since then there has been a gradual increase in requirements. They are expected to continue to increase to 39 750 m^3 a day (250 000 b/d) by the beginning of 1977 when Interprovincial's Montreal extension becomes fully operational. Remaining shipments of domestic crude oil went to refineries in Ontario and Western Canada.

Deliveries of imported crude oil to eastern Canadian refineries declined by 10 500 m^3 a day (66 000 b/d) to 120 000 cubic metres per day (755 316 b/d) — the decline reflecting the opening of the Sarnia-Montreal pipeline and the increased use of western Canadian crude oil in the Montreal refining area. Countries in the Middle East remained the largest source of crude oil imported into Canada, accounting for 49 per cent or 56 199 m^3 a day (353 000 b/d) of total Canadian imports. Middle East sources of imported oil were Iran, Saudi Arabia, Iraq, Kuwait and the Trucial States. Imports from Venezuela increased by 5 per cent to 42 822 m^3 a day (269 000 b/d) and continued to be Canada's second-largest source of imported crude oil. Imports of African oil from Nigeria and Libya increased by 35 per cent to 7699 m^3 a day (48 427 b/d).

The increase in demand for domestic crude oil was more than compensated for by a 32 273 m^3 a day (203 000 b/d), or 29 per cent, decline in exports to the United States, which averaged 79 351 m^3 a day (499 000 b/d) in 1976. This reduction is in line with the federal government's policy of phasing out all crude oil exports by 1981. The export control system commenced in 1974, and allowable exports are reviewed monthly by the NEB. At year-end, they were pegged at 61 205 m^3 a day (385 000 b/d) with further cutbacks anticipated in 1977.

United States refiners east of the Rocky Mountains took an average of 63 480 m^3 a day (399 300 b/d) of Canadian crude oil, 18 076 m^3 a day (133,700 b/d) less than last year, while refiners west of the Rockies in the Puget Sound area imported about 15 850 m^3 a day (99 700 b/d) of Canadian crude oil, about 12 560 m^3 a day (80 000 b/d) less than in 1975.

The phase-out of crude oil exports to the United States has created problems for heavy crude oil producers in western Canada, as there is a very restricted market for this type of crude oil in Canada. The end result has been that many heavy-oil fields have recently been operating at low capacity. Since it is expensive and difficult to reestablish normal production levels in heavy-gravity oil fields after production has been shut in, the immediate outlook for this sector of Canada's producing industry is a depressed one. In the face of our declining domestic oil supply this is an anomaly requiring attention, particularly since proven reserves of heavy oil are large. These resources could play a leading role in reducing Canada's anticipated oil supply shortage in the 1980s. Recognizing this fact, the NEB decided to license heavy oil exports to the United States separately from other oil exports on an interim basis starting January 1, 1977. As a result, total oil exports to the United States will drop to 49 125 cubic metres per day (309 000 b/d). The 49 131 cubic metres per day (309 000 b/d) export level will consist of up to 20 509 cubic metres per day (129 000 b/d) of designated heavy crude oil, plus 28 617 cubic metres per day (180 000 b/d) of light and medium crude oils. At year-end heavy oil exports were averaging only 12 720 cubic metres per day (80 000 b/d) including 3 975 cubic metres per day (25 000 b/d) of Lloydminster-type blends. The new export allocations were designed largely to ensure that a minimum export level of 3 975

Table 13. Canada, crude oil received at refineries, 1975 and 1976

Location of Refineries		Country of Origin							
		Canada	Middle East	Trinidad	Venezuela	Africa	Colombia	Other	Total Received
					(m³)				
Atlantic provinces	1975	6 043	13 450 648	91 964	4 721 266	63 820	—	30 707	18 364 448
	1976	28 351	9 373 558	61 470	5 177 817	196 915	—	16 721	14 821 390
Quebec	1975	387 301	16 782 514	29 946	10 136 987	2 032 729	—	388 906	29 758 384
	1976	4 837 634	11 195 353	—	10 495 240	2 621 068	—	2 476 938	31 626 234
Ontario	1975	25 676 340	—	—	47 299	—	—	—	25 723 639
	1976	26 182 563	—	—	—	—	—	273 334	26 455 896
Prairies	1975	16 579 742	—	—		—	—	—	16 579 742
	1976	16 573 399	—	—		—	—	—	16 573 399
British Columbia	1975	8 155 844	—	—		—	—	—	8 155 844
	1976	8 715 317	—	—		—	—	—	8 715 317
Northwest Territories	1975	157 882	—	—		—	—	—	157 881
and Yukon	1976	145 499	—	—		—	—	—	145 499
Total	1975	50 963 152	30 233 162	121 910	14 905 552	2 096 549	—	419 613	98 739 938
	1976	56 482 763	20 568 911	61 470	15 673 057	2 817 983	—	2 733 551	98 337 735

Source: Statistics Canada.
— Nil.

m^3 a day (25 000 b/d) of Lloydminster crude oil be maintained.

Exports of petroleum products in 1976, including propane and butane, amounted to 27 590 m^3 a day (174 000 b/d), about 1907 m^3 a day (12 000 b/d) less than in 1976. A softening in the market for Canadian refined petroleum products in the northeastern United States, combined with government curbs on exports of finished oils to these markets, was responsible for the decline. The large refineries in Quebec and the Maritimes that were constructed mainly to serve this market have been attempting to offset their export market losses by increasing sales in Quebec and, to a lesser degree, in Ontario. The closing of Newfoundland Refining Company Limited's 15 900 m^3 a day (100 000 b/d) refinery at Come-By-Chance has provided little relief for the remaining refineries as the Newfoundland refinery supplied no more than 5 per cent of the Quebec market. As a result, most refineries in Quebec and the Maritimes at year-end were operating at about 65 per cent capacity.

Imports of petroleum products again declined, totalling 5718 m^3 a day (36 000 b/d) compared to 6455 m^3 a day (40 000 b/d) in 1975. With the current surplus of refinery capacity in Canada, particularly in the eastern provinces, the trend to reduced imports of petroleum products is expected to continue. When gas plant production of natural gas liquids is taken into account, Canada became a net importer of crude oil and products for the first time since 1970 as imports exceeded exports by 18 840 m^3 a day (118 560 b/d).

The question of prices for oil and natural gas continued to occupy a major position in industry developments in 1976. No general agreement could be reached at the First Ministers' Conference held on May 6, 1976 to determine new price schedules for oil and gas. Later, after consultation with the producing provinces and under the authority of the Petroleum Administration Act, new prices of oil and gas were set. In respect to oil, the price, which had been frozen at $8 per .159 cubic metres (barrel) since July 1, 1975, was increased in two stages: by $1.05 per .159 cubic metres (barrel) on July 1, 1976 and another 70 cents per .159 cubic metres (barrel) on January 1, 1977, for an overall increase of $1.75 per .159 cubic metres (barrel).

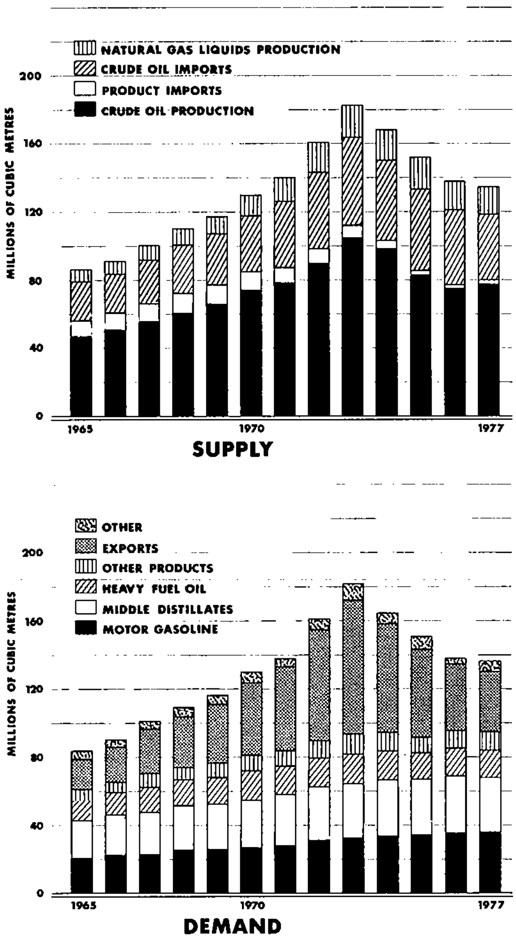
The federal government was again active in oil and gas developments during 1976. In April the Department of Energy, Mines and Resources released a report called "An Energy Strategy for Canada — Policies for Self-Reliance". The overall objective of the strategy adopted by the federal government, is self-reliance. Much of the report deals with oil and gas; the most immediate problems in Canada's energy supply picture. In support of the self-reliance objective, the Government of Canada has adopted a number of specific energy-related targets including: the movement of domestic oil prices towards international levels and domestic natural gas prices to appropriate relationship with oil over the next two to four years, a reduction of the average growth rate of energy use in Canada over the next ten years to less than 3.5 per cent a year, a reduction of Canadian net dependence on imported oil in 1985 to one third of our total oil demands, the maintenance of self-reliance in natural gas until such time as northern resources can be brought to market under acceptable conditions, and at least the doubling of exploration and development in the frontier areas of Canada over the next three years,

Table 14. Consumption of petroleum products by province, 1976[p]

	Motor Gasoline	Kerosene, Stove Oil, Tractor Fuel	Diesel Fuel Oil	Light Fuel Oils #2 and 3	Heavy Fuel Oils #4, 5 and 6.
			(m^3)		
Newfoundland	579 582	162 395	429 802	505 387	584 366
Atlantic provinces	2 378 099	376 776	967 411	2 053 201	3 846 014
Quebec	8 623 477	888 701	2 263 271	6 754 948	6 561 671
Ontario	12 615 674	358 645	2 669 723	5 968 443	3 989 079
Manitoba	1 549 030	122 765	693 287	242 151	177 372
Saskatchewan	2 058 923	207 007	866 948	208 317	18 880
Alberta	3 897 722	70 570	1 788 347	132 241	71 243
British Columbia	3 651 791	196 193	1 758 164	962 716	1 453 781
Northwest Territories and Yukon	89 945	58 903	206 466	107 864	24 774
Total	35 444 243	2 441 955	11 643 419	16 935 268	16 727 180

Source: Statistics Canada.
[p] Preliminary.

PETROLEUM SUPPLY- DEMAND in CANADA



SOURCE : STATISTICS CANADA

under acceptable social and environmental conditions. Although the strategy has been designed to deal with problems to be faced over the next 10 to 15 years, it recognizes that it is necessary to look to a time when oil and natural gas will no longer supply most of Canada's energy. Building on the report's scenarios, longer-term issues will be addressed in a subsequent paper that will examine alternative energy futures beyond 1990.

In May 1976 the federal government announced the elements of a Petroleum and Natural Gas Act which is expected to be placed before Parliament sometime in 1977. The Act will provide for a new regulatory system to govern the manner in which oil and gas rights are made available for development in Canada's territories and offshore regions. This new legislation is designed to promote the early assessment of Canada's frontier oil and gas resources through incentives to explore and disincentives to allow land to remain idle, and by granting the necessary authority to require a certain pace in exploration permit evaluation. This is in accordance with the goal of self-reliance and the elements of the national energy strategy announced in late-April, 1976. Given the desirability of reducing our dependence of foreign oil there is an essential "need to know" associated with the early delineation of Canada's resource base. There are also elements to stimulate exploration which include fiscal and land-holding incentives, together with complementary provisions for greater government control over the timing, direction, rate and level of exploration, development and production activities. In addition, the legislation will permit Canadian firms, including Petro-Canada to benefit more fully from the development of the resource base.

Later in the year Petro-Canada had completed formal acquisition of all outstanding common shares of Atlantic Richfield Canada Ltd. for an agreed price of $340 million. The price reflects asset value, with adjustment for net working capital. The assets consist essentially of producing oil and gas properties, exploration acreage and an Athabasca oil sands lease interest.

Table 15. Canada, exports and imports of refined petroleum products, 1975-76

	Exports		Imports	
	1975	1976ᵖ	1975	1976ᵖ
	(000 m³)			
Propane and butane	5 794	6 711	10	12
Aviation gasoline	—	—	3	6
Motor gasoline	651	501	31	7
Aviation turbo fuel	104	—	112	28
Kerosene, stove oil and tractor fuel	9	9	32	56
Diesel fuel oil	183	10	114	66
Light fuel oil #2 and 3	840	78	193	29
Heavy fuel oil #4, 5 and 6	3 103	2 528	1 168	1 053
Asphalt	—	—	28	14
Petroleum coke	27	—	482	498
Lubricating oils and greases	—	—	207	209
Other products	256	184	76	128
Total, all products	10 967	10 021	2 456	2 106

Sources: Statistics Canada and National Energy Board.
ᵖPreliminary; — Nil.

Table 16. Canada, supply and demand of oils, 1975-1976

	1975[r]	1976[p]
	(000 m³)	
Supply		
Production		
Crude oil and condensate	82 802	75 993
Other natural gas liquids	17 835	16 622
Net production	100 637	92 615
Imports		
Crude oil	47 796	41 883
Products	2 359	2 093
Total imports	50 155	43 976
Change in stocks		
Crude and natural gas liquids	− 1 030	+ 943
Refined petroleum products	+ 734	+ 2 017
Total change	− 296	+ 2 960
Oils not accounted for	+ 575	+ 609
Total supply	151 071	140 160
Demand		
Exports		
Crude Oil	40 849	29 044
Products	10 811	10 101
Total exports	51 660	39 145
Domestic sales		
Motor gasoline	34 426	35 298
Middle distillates	33 218	34 637
Heavy fuel oil	15 495	16 643
Other products	8 664	9 354
Total sales	91 803	95 932
Uses and losses		
Refining	6 705	5 931
Field plant and pipeline	+450	+479
Losses and adjustments[1]	+453	−1 327
Total uses, losses and adjustments	7 608	5 083
Total demand	151 071	140 160

Sources: [1]Statistics Canada and provincial government reports.
[p]Preliminary; [r]Revised.

The oil sands lease amounts to a one third interest in 1.2 million acres with an *in situ* development potential. The Atlantic Richfield name will be changed to Petro-Canada Exploration Inc., but it will continue operation, development and production activities. Petro-Canada president W.H. Hopper has been named chairman, D.W. Axford, Petro-Canada Exploration vice-president, is president and Sam Stewart, vice-president of Atlantic Richfield, becomes executive vice-president and chief operating officer.

Phosphate

B.W. BOYD

In 1976 world sales of phosphate rock increased slightly over sales in 1975, but did not reach the level achieved in 1974. The main factor causing the depressed market in both 1975 and 1976 was the price of rock exported from Morocco and the United States. Over the period from 1974 to 1975 the Moroccan phosphate rock producer, Office Cherifien des Phosphates (OCP), quintupled the price of rock for export and then, as buyer resistance reduced sales, lowered the price in 1976 to about double the price in the base year 1973. The U.S. exporters followed OCPs lead but were less extreme in their raising and lowering of prices.

Phosphate is a term applied to a rock, mineral, or salt containing one or more phosphorous compounds. About four-fifths of the world's phosphate consumption is for agriculture — largely fertilizers. World demand for phosphate rock expanded at unprecedented rates from 1963 to 1967 to meet the needs of a rapidly developing phosphate fertilizer industry. The demand eased considerably between 1968 and 1971 because of overcapacity in the industry, resulting in decreased prices, and a lessening demand for fertilizer arising from lower farm product prices. A worldwide food shortage that assumed serious proportions in 1970-71, carried through to 1974. This shortage was accompanied by higher food prices and a sharp increase in the demand for fertilizers, including phosphates. The fertilizer price increases in 1974 and 1975 broke the trend and in spite of an increase in the need for fertilizer to boost food production, actual sales in 1976 were below the 1974 level.

In Canada consumption of phosphate rock continued to fall throughout 1975 and 1976 as Canadian fertilizer production was cut back. Imports of phosphate rock fell by 27 per cent in 1976 while the value of imports fell by 32 per cent relative to 1975 levels. The Canadian fertilizer industry lost markets to the United States fertilizer industry throughout 1975 and the first half of 1976. The situation improved in the autumn of 1976 when the price of phosphate rock fell, while prices for fertilizer increased.

Phosphate rock

Phosphate rock contains one or more suitable phosphate minerals, usually calcium phosphate, in sufficient quantity for use either directly or after beneficiation in the manufacture of phosphate products. Sedimentary phosphate rock, or phosphorite, is the most widely used phosphate raw material; apatite, which occurs in many igneous and metamorphic rocks, and can be represented by the formula $Ca_5(PO_4)_3$ (F,Cl,OH), is second in importance. Other sources of phosphate include guano and a basic slag byproduct of some steel mills. Phosphate rock can be decomposed by three methods: acid treatment, thermal reduction, or thermal treatment without reduction. Canadian phosphate producers use the first two methods.

Phosphate rock is graded either on the basis of its P_2O_5 equivalent (phosphorus pentoxide) or $Ca_3(PO_4)_2$ content (tricalcium phosphate or bone phosphate of lime — TPL or BPL). For comparative purposes, 0.458 P_2O_5 equals 1.0 BPL, and one unit of P_2O_5 contains 43.6 per cent phosphorus.

Occurrences in Canada

Although there are numerous occurrences of low-grade phosphate rock in Canada, there is no commercial production. Large quantities of rock are imported, mostly from the United States, for use in the manufacture of agricultural and industrial products sold in domestic and export markets.

Known Canadian deposits are limited and fall into three main categories: apatite deposits within Precambrian metamorphic rocks in eastern Ontario and southwestern Quebec; apatite deposits in some carbonate-alkaline complexes (carbonatites) in Ontario and Quebec; and Late Paleozoic-Early Mesozoic sedimentary phosphate rock deposits in the southern Rocky Mountains.

The Precambrian metamorphic apatite deposits of Ontario and Quebec occur in pyroxenites as small, irregular, scattered pockets and veins with phlogopite mica and pink calcite. Most of the outcrops are in the Rideau Lakes region of eastern Ontario and the Lievre River area of southwestern Quebec where many deposits were worked extensively between 1869 and 1900, before low-cost Florida rock entered world markets.

Carbonatites usually occur as roughly circular plugs

Table 5. Canada, phosphorus and phosphate fertilizer plants, 1975

Company	Plant Location	Annual Capacity	Principal End Products	Basis for H_2SO_4 Supply for Fertilizer Plants
		(tonnes)		
Elemental phosphorus				
Erco Industries Limited	Varennes, Que.	18 000	el ph	
	Long Harbour, Nfld.	72 500	el ph	
Total elemental phosphorus		90 500		
Phosphate fertilizer		(P_2O_4 eq.)		
Canada Wire and Cable Limited[1]	Belledune, N.B.	113 000	am ph	SO_2 smelter gas
Canadian Industries Limited	Beloeil, Que.	18 000	ss	sulphur
	Courtright, Ont.	84 000	am ph	SO_2 pyrrhotite, Copper Cliff
Cominco Ltd.	Kimberley, B.C.	117 000	am ph	SO_2 smelter gas
	Trail, B.C.	76 000	am ph	SO_2 smelter gas
International Minerals & Chemical Corporation (Canada) Limited	Port Maitland, Ont.[2]	189 000	H_3PO_4, ss ts, ca ph	sulphur, SO_2 smelter gas
Green Valley Fertilizer & Chemical Co. Ltd.	North Surrey, B.C.	900	ss	SO_2 smelter gas Trail
Imperial Oil Limited	Redwater, Alta.	191 000	am ph	sulphur
St. Lawrence Fertilizers Ltd.[3]	Valleyfield, Que.	51 000	ts, am ph	SO_2 smelter gas
Sherritt Gordon Mines Limited	Fort Saskatchewan, Alta.	59 000	am ph	sulphur
Simplot Chemical Company Ltd.	Brandon, Man.	. .	am ph	imports H_3PO_4
Western Co-operative Fertilizers Limited	Calgary, Alta.	109 000	am ph	sulphur
	Medicine Hat, Alta.	64 000		
Total, phosphate fertilizer		1 071 900		

el ph Elemental phosphorus; P_2O_5 eq. Phosphorus pentoxide equivalent; am ph Ammonium phosphates; ss Single superphosphate; ts Triple superphosphate; ca ph Food supplement calcium phosphate; . . . Not applicable, H_3PO_4 is made elsewhere. [1]Noranda Mines Limited acquired full ownership of Belledune Fertilizer Limited, effective April 1, 1972, name changed to Canada Wire and Cable Limited, June 5, 1972. [2]Operates at less than annual capacity because of environmental restrictions. [3]Closed in April 1976.

Carolina. Four major projects are planned for Florida with the potential to increase production by 8.5 million tonnes per year before 1980.

Australia has reinstituted its superphosphate bounty which subsidizes farmers' use of fertilizer and will doubtless increase phosphate consumption in that country.

Production, trade and consumption

Nearly all Canada's trade in phosphate fertilizers is with the United States. Under foreign aid programs shipments are occasionally made to southeast Asian countries. Preliminary figures indicate that imports of phosphate rock in 1976, at 2 386 513 tonnes were nearly 900 000 tonnes less than in 1974. Phosphate fertilizer production increased by 58 816 tonnes to 719 725 tonnes P_2O_5 equivalent.

Imports of phosphate fertilizer increased for the second year in a row. United States products are now infiltrating the western Canadian market as the production cost differential between United States and Canadian producers exceeded the high freight costs which previously insulated this market. Fertilizer imported from the United States entered the domestic

Table 6. Canada, trade in selected phosphate products, 1975-76

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Imports				
Calcium phosphate				
United States	12 711	3 318 000	17 709	4 651 000
United Kingdom	10	4 000	18	10 000
Other countries	1	. . .	—	—
Total	12 722	3 322 000	17 727	4 661 000
Fertilizers				
Normal superphosphate, 22% P_2O_5 or less				
United States	2 898	194 000	1 367	126 000
Triple superphosphate, over 22% P_2O_5				
United States	42 825	6 581 000	26 248	2 384 000
Phosphate fertilizers, nes				
United States	81 566	14 981 000	140 572	19 192 000
Belgium and Luxembourg	538	246 000	258	87 000
United Kingdom	182	115 000	33	16 000
Netherlands	36	19 000	4	2 000
Total	82 322	15 361 000	140 867	19 297 000
Chemicals				
Potassium phosphates				
United States	2 894	1 591 000	1 979	1 196 000
Sodium phosphate tribasic				
United States	1 945	563 000	709	240 000
Netherlands	—	—	28	6 000
Total	1 945	563 000	737	246 000
Sodium phosphate, nes				
United States	4 727	2 320 000	4 321	2 358 000
West Germany	116	69 000	127	70 000
United Kingdom	4	9 000	—	—
Total	4 847	2 398 000	4 448	2 428 000
Exports				
Nitrogen-phosphate fertilizers, nes				
United States	373 382	67 063 000	363 546	49 187 000
Italy	—	—	44 506	6 397 000
Pakistan	27 917	8 043 000	16 964	3 778 000
Ethiopia	—	—	15 034	2 102 000
Thailand	—	—	15 884	1 284 000
France	—	—	5 387	1 183 000
Japan	1 748	313 000	3 795	631 000
Belgium and Luxembourg	40 292	7 776 000	4 556	378 000
Ireland	5 505	1 026 000	—	—
Total	448 844	84 221 000	469 672	64 940 000

Source: Statistics Canada.
^{p} Preliminary; nes Not elsewhere specified; — Nil; . . . Less than $1 000.

Table 7. Canada, phosphate fertilizer consumption and trade, years ended June 30, 1967-76

	Consumption	Imports[1]	Exports
	(tonnes P_2O_5 equivalent)		
1967	373 954	67 074	125 312
1968	399 246	39 668	149 729
1969	315 531	21 821	146 103
1970	280 683	10 245	198 221
1971	326 388	10 361	307 335
1972	340 813	39 831	272 795
1973	415 295	47 447	300 752
1974	494 230	30 095	247 600
1975	501 688	29 976[r]	180 561
1976[p]	502 657	95 310	200 713

Source: Statistics Canada.
[1]Excludes nutrient content of mixtures and of orthosphoric acid.
[p]Preliminary; [r]Revised.

Table 8. Listed export prices for Florida phosphate rock

Grade	October 1974	January 1976
($U.S. per tonne fob Tampa or Jacksonville)		
77/76% TPL	62.00	. .
75/74% TPL	55.00	47.00
72/70% TPL	48.00	41.00
70/68% TPL	43.00	37.00
68/66% TPL	39.00	33.00
66/64% TPL	36.00	30.00

Source: British Sulphur Corporation Limited.
. . Not available.

market usually served by Canadian producers when the cost of imported phosphate rock increased in 1974 and 1975 and forced up the selling price of Canadian fertilizer product. Many United States fertilizer producers have captive phosphate rock mines and because they were insulated from the dramatic increases in the price of rock they could undersell the Canadian producers. In the export market also, Canadian product was supplanted by United States fertilizer. Consequently, exports continued at a low level, only 21 128 tonnes above exports in 1975 and still 169 541 tonnes below the level of 1974.

Outlook

World demand for phosphate fertilizer is projected to increase at a rate of four per cent annually over the next five years. Excess production capacity for fertilizer exists now and planned plant expansions exceed the projected growth rate of demand. The control by the United States and Morocco of large parts of the total rock supply and the formation of U.S. and African producer associations will probably stabilize price of rock at current levels or higher.

In the United States, where fertilizer production capacity is expanding, and in Morocco and other African and Middle East countries the trend is to tie fertilizer production to the production of phosphate rock. Considering the excess world capacity for fertilizer production and the control of rock production by a small number of countries, most of which also producer fertilizer, the foreseeable situation is for relatively low fertilizer prices and high rock prices.

Canadian producers must accept that United States producers of both phosphate rock and fertilizer will continue to exert tight control over the prices throughout North America. Although sales will be good during short-term, high-demand periods it is unlikely that an expansion of Canadian production will be a profitable venture. Also, in spite of high prices for phosphate rock a depressed fertilizer industry will not likely be prepared to finance development of Canadian phosphate rock resources.

Table 9. Listed export prices for Moroccan phosphate rock

Grade	January 1975	January 1976	January 1977
($U.S. per tonne fas Casablanca, Safi or El Aaiun)			
Bu Craa 80/82% TPL	—	54.00	44.00
Khouribga			
77/79% TPL (calcined)	76.50	51.50	41.75
75/77% TPL	68.00	48.50	39.50
70/72% TPL	65.00	46.00	38.00
Youssoufia			
70/72% TPL	60.75	43.00	35.25

Source: British Sulphur Corporation Limited.
— Nil.

Platinum Metals

J.J. HOGAN

The platinum group metals consist of platinum, palladium, rhodium, iridium, ruthenium and osmium, the first two being by far the more abundant and important. The metals are usually found in basic and ultrabasic rocks, generally associated with nickel and copper sulphides, and in placer deposits, although production from placers is now of minor importance. The major sources of platinum metals are mines worked principally for these metals, mainly in the Republic of South Africa, and as a byproduct from the treatment of nickel-copper ores. A small amount of platinum is recovered from the refining of copper ores.

The major producers, ranked in decreasing order of production volume, are the Republic of South Africa, the U.S.S.R. and Canada. Minor producers are Colombia, the United States, Japan, Australia, and the Philippines.

Canadian production of platinum group metals in 1976 was estimated at 13 374 000 grams (g) valued at $48 790 000 compared with 12 417 099 g in 1975 valued at $56 493 077. Although volume of production increased 7.7 per cent the dollar value declined 13.6 per cent because of the low selling price for platinum and palladium in 1976. Platinum metals output in Canada is derived as a byproduct of nickel-copper refining operations in the Sudbury district of Ontario and the Thompson district of Manitoba.

World primary production of platinum group metals in 1976 was estimated by the United States Bureau of Mines (USBM) at 184 754 kilograms (kg) compared with 179 249 kg in 1975. In 1975 the two major producers of platinum metals in the Republic of South Africa initiated a 25 per cent reduction in output to bring about a better balance between supply and demand. In the early part of 1976, on indications of an increase in the world's business activity, the companies announced plans to restore part of their previous production cutbacks in order to meet the expected increase in demand. Later in the year the companies had to modify their anticipated annual production rate increase because of a weakness in demand.

South Africa was the leading world producer of platinum metals in 1976 followed closely by the U.S.S.R. These two countries accounted for 91.6 per cent of the world output in 1976 and Canada, the third largest producer, accounted for 7.3 per cent.

The United States and Japan were the leading consumers of platinum metals in the non-communist world in 1976 with preliminary estimates showing the United States surpassing Japan as the largest consumer because of a substantial increase in the demand for platinum and palladium by the United States automotive industry for use in catalytic converters to control emission pollutants, and a decreased demand for platinum by the Japanese jewellery industry.

Japan is normally the largest consumer of platinum and accounts for about 50 per cent of total world consumption. The consumption of platinum by industry in Japan in 1976 was estimated at 43 700 kg. The jewellery trade consumed an estimated 71 per cent of the country's total platinum consumption.

The USBM estimated the platinum group metals sold to industry in the United States in 1976 at 52 876 kg. The percentage of platinum group metals sold to the U.S. consuming industries were: platinum, 54.1; rhodium, 2.8; iridium, 0.6; palladium, 40.3; ruthenium, 2.1 and osmium, 0.1.

The major consumers in the United States are the automotive, chemical and electrical industries which together account for about 72 per cent of the total. The automotive industry accounted for 41 per cent of the platinum metals consumed in 1976. Preliminary estimates show the consumption of platinum and palladium in the U.S. automotive industry at approximately 14 650 kg and 5 972 kg, respectively, in 1976, substantially above the 8 491 kg and 3 017 kg consumed in this industry in 1975. The USBM reports the stocks of platinum group metals held by refiners, importers and dealers in the United States, including metal in depositories of the New York Mercantile Exchange but not platinum metals contained in United States government stockpile at the end of 1976, at 32 271 kg compared with 26 413 kg at the end of 1975.

Canadian operations and developments

The platinum group metals produced in Canada were

Table 1. Platinum metals, production and trade 1975-76

	1975		1976[p]	
	(grams)	($)	(grams)	($)
Production[1]				
Platinum, palladium, rhodium, ruthenium, iridium	12 417 099	56 493 077	13 374 000	48 790 000
Exports				
Platinum metals in ores and concentrates				
United Kingdom	13 370 358	43 009 000	12 025 692	39 178 000
Norway	100 837	434 000	—	—
United States	—	—	45 722	120 000
Total	13 471 195	43 443 000	12 071 414	39 298 000
Platinum metals, refined				
United States	553 393	2 074 000	892 483	2 970 000
United Kingdom	1 417 883	4 350 000	724 804	2 846 000
West Germany	84 725	355 000	30 512	197 000
Other countries	3 733	22 000	6 874	8 000
Total	2 059 734	6 801 000	1 654 673	6 021 000
Platinum metals in scrap				
United States	536 472	2 681 000	637 216	2 930 000
United Kingdom	98 535	385 000	334 113	1 683 000
West Germany	30 699	79 000	—	—
Total	665 706	3 145 000	971 329	4 613 000
Re-export[2]				
Platinum metals, refined and semiprocessed	538 898	2 928 000	383 972	1 618 233
Imports				
Platinum lumps, ingots, powder and sponge				
United States	137 135	742 000	186 714	825 000
United Kingdom	24 416	135 000	5 536	13 000
Panama	622	2 000	—	—
Total	162 173	879 000	192 250	838 000
Other platinum group metals				
United States	1 383 607	3 793 000	706 484	2 103 000
South Africa	174 179	444 000	410 565	593 000
United Kingdom	176 450	944 000	16 018	36 000
Total	1 734 236	5 181 000	1 133 067	2 732 000
Total platinum and platinum group metals				
United States	1 520 742	4 535 000	893 198	2 928 000
United Kingdom	200 866	1 079 000	21 554	49 000
South Africa	174 179	444 000	410 565	593 000
Panama	622	2 000	—	—
Total	1 896 409	6 060 000	1 325 317	3 570 000

Table 1 (concl'd)

	1975		1976^p	
	(grams)	($)	(grams)	($)
Platinum crucibles[3]				
United States	530 687	3 836 000	697 433	4 711 000
Switzerland	62	. . .	—	—
United Kingdom	31	. . .	—	—
Total	530 780	3 836 000	697 433	4 711 000
Platinum metals, fabricated materials, not elsewhere specified				
United Kingdom	833 728	4 522 000	791 770	4 343 000
United States	823 402	913 000	302 325	1 341 000
South Africa	—	—	46 655	80 000
Nigeria	—	—	15 987	62 000
Total	1 657 130	5 435 000	1 156 737	5 826 000

Source: Statistics Canada
[1]Platinum metal, content of concentrates, residues and matte shipped for export. [2]Platinum metals, refined and semiprocessed, imported and re-exported after undergoing no change or alteration. [3]Includes spinners and bushings.
^p Preliminary; — Nil; . . . Less than $1 000.

recovered as a byproduct from the treatment of the nickel-copper sulphide ores, principally those in the Sudbury district of Ontario and the Thompson-Wabowden region of Manitoba. In processing these ores for recovery of nickel and copper, the platinum metals concentrate in the sludge formed during the electrolytic refining of the nickel-copper anodes. The sludge produced by Inco Limited (Inco) is shipped to its refinery at Acton, England for the extraction and refining of the platinum metals. Falconbridge Nickel Mines Limited ships nickel-copper matte from its Falconbridge, Ontario plant to its refinery in Kristiansand, Norway. The sludge collected from this operation is shipped to Engelhard Minerals & Chemicals Corporation at Newark, New Jersey for recovery of the contained platinum metals. In Canada, the metal percentages of the platinum group metals are approximately 46 per cent platinum, 40 per cent palladium and 14 per cent other platinum metals.

Inco, the largest producer of platinum group metals in Canada, operated 11 nickel-copper mines, 5 concentrators, a nickel-copper smelter and a nickel pellet and powder refinery in the Sudbury area of Ontario. Elsewhere in Ontario Inco operated a nickel refinery at Port Colborne and a mine-concentrator complex at Shebandowan near Thunder Bay. Falconbridge Nickel, Canada's second-largest nickel producer, operated 4 nickel-copper mines, 2 concentrators and a smelter in the Sudbury district.

In the Timmins area the Langmuir mine, owned 51 per cent by Noranda Mines Limited and 49 per cent by Inco, shipped its concentrates to the Inco Smelter at Copper Cliff. Kanichee Mining Incorporated, near Temagami, a shipper to Falconbridge's smelter, closed its mining operation in February, 1976. In August 1976 Union Minière Explorations and Mining Corporation Limited (UMEX) began operating its 3 600-tonne*-a-day concentrator at its Thierry deposit near Pickle Lake, Ontario. A copper concentrate containing nickel and precious metals is shipped to the Noranda smelting and refining facilities in Quebec for the recovery of these metals.

In Ontario, Inco has two mines being maintained on a standby basis and is developing two mines for production. Falconbridge Nickel has four mines and a concentrator in the Sudbury district being maintained on a standby basis but work was under way at year-end to reactivate one of these mines. Falconbridge is also developing two new mines in the Sudbury area.

Texasgulf Inc., after considerable diamond drilling, dropped its option on the Lac des Iles platinum-palladium property of Boston Bay Mines Limited in northwestern Ontario. It was reported that the work done to date by Boston Bay and Texasgulf has outlined two zones of mineralization estimated to contain about 35 000 tonnes per vertical metre grading 5.75 grams of platinum metals a tonne, 0.2 per cent copper-nickel and 0.62 grams of gold a tonne. Preliminary work indicated the ratio of palladium to platinum is about 8 to 1.

Three companies in Manitoba recovered platinum metals from nickel-copper sulphide ores. Inco operated three mines and a concentrator-smelter-refinery complex and has one mine being maintained on a standby basis in the Thompson region. The sludge from the refining process containing the precious metals is shipped to Port Colborne, Ontario for recovery of these metals. At Wabowden, Falconbridge Nickel operated a

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

mine and concentrator and shipped the concentrates to its smelter in Ontario. This mine is scheduled for closure in the early part of 1977 because of exhaustion of ore reserves. Ore from Dumbarton Mines Limited, in the Bird River area, was custom-treated at the Werner Lake concentrator of Consolidated Canadian Faraday Limited in Ontario. The nickel-copper concentrate produced was shipped to the Falconbridge smelter in the Sudbury district. The mine was closed in 1976. Sherritt Gordon Mines Limited closed its nickel-copper mine at Lynn Lake, but the hydro-metallurgical process used by this company to recover nickel does not lend itself to the economic recovery of platinum metals.

Foreign developments

Republic of South Africa: The Republic of South Africa is one of the world's largest producers of platinum group metals. It is the only country among the major world producers that mines platinum metals-bearing ores primarily for the recovery of these metals. The deposits, which occur in the Merensky Reef of the Bushveld Complex near Rustenberg, also contain some gold, copper and nickel. Platinum group metals recovered from the ores contain approximately 61 per cent platinum, 25 per cent palladium and 14 per cent other platinum group metals. Small amounts of osmium and iridium are recovered as a byproduct from treatment of the Witwatersrand gold ores.

In the first part of 1976 it appeared there would be a significant improvement in the world's economy and the demand for metals would increase. The major platinum metals producers in South Africa announced plans to increase their output to be able to meet the expected increase in market demand. The improvement in business activity did not develop as predicted and the producers had to make adjustments to their planned production increases. Operating costs increased by about 20 per cent during the year because of wage awards made to both the African and European workers, and because of the continuing escalation in the cost of supplies and services.

Rustenberg Platinum Mines Limited, a wholly-owned subsidiary of Rustenberg Platinum Holdings Limited and the largest platinum metals producer in the non-communist world, operated three mines, a smelter and two refineries in the Transvaal district of South Africa and two refineries in the United Kingdom. One mine property is located in the Rustenberg district and two in the Union district of the Transvaal. The refining of the mine output is carried out in the Republic of South Africa and in the United Kingdom by Matthey Rustenberg Refineries (Proprietary) Limited which was incorporated on March 13, 1972 and is jointly owned by Rustenberg, and Johnson, Matthey & Co., Limited of the United Kingdom. The expansion of the matte-treatment facilities at the Rustenberg plant of Matthey Rustenberg Refiners, which included a new process for the treatment of the converter matte output, was completed during the year. The new process substantially reduces the time required and the costs involved in the treatment and refining of the platinum group metals. This new plant resulted in the closure of the Matthey Rustenberg plant at Brimsdown in the United Kingdom.

In 1975 Rustenberg reduced its annual rate of production to about 27 993 kg a year to bring supply in line with demand. The program to increase the capacity of Rustenberg's plants from its present-rated annual output of 38 880 kg of platinum metals to 50 700 kg is being carried out on a flexible basis to correspond with projected demand for the metals. In the early part of 1976 it appeared that demand for platinum metals would improve and plans were made to increase the rate of capital expenditures to increase output. The rate of growth in the industrial countries was slower than expected and later in the year capital expenditures were reduced. The first milling circuit at Rustenberg's new mine at Amandelbat was completed. There are no

Table 2. Canada, platinum metals, production and trade; 1965, 1970 and 1974-76

	Production[1]		Exports				Imports[4]	
			Domestic[2]		Re-export[3]			
	(grams)	($)	(grams)	($)	(grams)	($)	(grams)	($)
1965	14 404 859	36 109 799	17 138 699	30 103 254	10 013 764	11 389 395	7 265 865	13 461 546
1970	15 005 188	43 556 597	20 219 312	43 174 000	634 479	2 365 735	1 889 380	3 123 000
1974	11 962 957	60 794 030	17 140 410	62 233 000	1 177 981	3 680 000	1 527 927	6 847 000
1975	12 417 099	56 493 077	15 530 929	50 244 000	538 898	2 928 000	1 896 409	6 060 000
1976[p]	13 374 000	48 790 000	13 726 087	45 319 000	383 972	1 618 233	1 825 317	3 570 000

Source: Statistics Canada.
[1]Platinum metals, content of concentrates, residues and matte shipped for export. [2]Platinum metals in ores and concentrates and platinum metals, refined. [3]Platinum metals, refined and semi-processed, imported and re-exported after undergoing no change or alteration. [4]Imports, mainly from United States and Britain, of refined and semi-processed platinum metals, derived from Canadian concentrates and residues, a large part of which is re-exported.
[p]Preliminary.

plans to increase the rate of production at this mine beyond the capacity of the one milling unit, although two additional milling units could be brought into production in a comparatively short period should the demand for the metals increase.

Mine production costs per tonne of ore mined increased by about 20 per cent in 1976 over the previous year. To offset increasing costs Rustenberg has undertaken a program to mechanize its underground operations and in 1976 about one-half of the ore mined came from mechanized stopes. The company reported that operating costs in the mechanized stopes were reduced substantially.

To date, all production from the Rustenberg operations comes from the Merensky Reef. A second reef, which contains chrome and platinum group metals and is known as the Upper Group No. 2 Reef (UG2), occurs beneath the Merensky Reef. Rustenberg has set up a small pilot plant to determine the problems associated with mining this reef and to develop a process to recover economically its chrome ore and precious metals. The company estimates that it will take at least a year to complete the feasibility study. Successful development of this zone will add to the large reserves already developed in the Merensky Reef.

Sales of the company's metal are made through Rustenberg's marketing agent, Johnson, Matthey & Co., Limited. A part of the Company's output is purchased by Engelhard Minerals & Chemicals Corporation under long-term sales agreements made with that company on January 1st, 1972.

Impala Platinum Limited operates a mine-concentrator-smelter-refinery complex near Rustenberg. In the early part of 1976 Impala announced an increase in its planned production rate from 18 660 kg of platinum metals a year to 21 770 kg to take advantage of an expected improvement in the economy. The proposed production increase would be subject to periodic review in light of changing market conditions and the labour situation.

Western Platinum Limited, jointly owned by Lonrho Limited, Falconbridge Nickel Mines Limited and Superior Oil Company, operated a mine-concentrator-smelter complex with an annual rated capacity of 4 666 kg of platinum metals in the Transvaal district of South Africa. Production of platinum group metals for the fiscal year ending September 30, 1976 was 4 137 kg compared with 3 982 kg for the fiscal year 1975. Problems related to labour were responsible for production being below the rated capacity of the plant. Substantial increases in wage rates, supplies and services forced operating costs up sharply. The bulk of the platinum and palladium output from this property is under contract until the end of 1978 and adjustments to meet market conditions are therefore not necessary at this time.

Atok Platinum Mines (Proprietary) Limited near Pieterburg, Transvaal is a small producer of platinum group metals, plant capacity being about 1 244 kg. Shortage of labour at the mine, weak platinum metals demand and low metal prices adversely affected the operation.

U.S.S.R.: In the U.S.S.R. platinum metals are derived mainly as a byproduct in the processing of nickel-copper ores in the Norilsk region of northwestern Siberia and the Kola Peninsula of northwest Russia. Small amounts of platinum metals are recovered from placer deposits in the southern Urals. The United States Bureau of Mines (USBM) estimated the U.S.S.R. production of platinum metals at 83 980 kg for the year 1976, compared with 82 424 kg in 1975. The U.S.S.R. is carrying out a major expansion program to develop nickel-copper deposits in the Norilsk region to substantially increase the output of these metals. The program is being carried out on a phase basis, and the first phase, the preparation of a major new underground mine for production, was to be completed by 1975. A second major underground mine is also under development. A new nickel-copper smelter complex to treat the increased tonnage is under construction; the first phase, according to reports, is expected to be completed in 1977. The overall expansion program is expected to be completed by 1980. Based on the platinum metals content of the producing mines in the Norilsk region, this expansion program should add substantially to the quantity of platinum metals, especially palladium, produced in the U.S.S.R. The percentages of platinum metals in the U.S.S.R. ores are about 60 per cent palladium, 30 per cent platinum and 10 per cent other platinum metals.

United States: Mine production of platinum metals in the United States was derived from a placer deposit in the Goodnews Bay area of Alaska and as a byproduct of gold and copper refining. The United States also recovered a substantial quantity of platinum metals from secondary sources. The company recovering platinum metals from the placer deposits of the Goodnews Bay area closed early in 1976. The USBM estimated new and secondary platinum metals recovered in 1976 by refiners in the United States at 6 438 kg. Mine production of platinum metals was estimated at 560 kg compared with 591 kg in 1975.

Platinum group metals are found in the rocks of the Stillwater complex, Sweetgrass County, southwestern Montana. Johns-Manville Corporation has carried out an extensive underground program consisting of drifting and diamond drilling, and surface diamond drilling, to evaluate the property. Significant values in platinum metals have been encountered as well as smaller amounts of copper-nickel sulphides, silver and gold.

Colombia: Production of platinum metals in Colombia was estimated by the USBM at 684 kg in 1976, the same as in 1975. The platinum metals are recovered as a coproduct with gold from placer operations in the Chaco and Narimo districts of Colombia.

Table 3. World mine production of platinum group metals, 1974-76

	1974	1975	1976^{e}
		(grams)	
Republic of South Africa	88 178 357	81 553 300	84 446 000
U.S.S.R.	77 758 692	82 424 200	83 979 000
Canada	11 962 957	12 417 100	13 374 000
Colombia	653 173	684 300	684 000
United States	404 345	591 000	560 000
Other countries	590 966	622 100	778 000
Total	179 548 490	178 292 000	183 821 000

Sources: U.S. Bureau of Mines *Minerals Yearbook Preprint 1974* for the year 1974. U.S. Bureau of Mines Commodity Data Summaries, January 1977, for 1975 and 1976; Statistics Canada for Canadian production.
^{e} Estimated.

Uses

The main applications for the platinum group metals are the jewellery, automotive, chemical, petroleum refining, glass and electrical industries. The industrial uses of platinum group metals are based on special properties, the principal ones being: catalytic activity, resistance to corrosion and to oxidation at elevated temperatures, good electrical characteristics, high melting point, high strength, good ductility and aesthetic qualities. Platinum and palladium are the major platinum metals. The others, namely iridium, osmium, rhodium and ruthenium, are used mainly as alloying elements with platinum and palladium but small amounts are also used in special applications.

The recent development of the use of platinum and palladium in catalytic converters for the control of automotive exhaust emissions has been a major factor in increasing the demand for these metals and was responsible for the recent expansion of production facilities in South Africa. The Environmental Protection Agency (EPA) of the United States has established automotive emission standards which generally require platinum-palladium converters to attain them. Japan is the only other country that has set emission standards which require catalytic converters to meet them. It is expected that rhodium will also be used to meet the stricter standards set by the EPA for the future. Platinum metals catalysts are also used on a limited scale in other emission control systems where clean exhausts are required, including fume abatement in catalytic incinerator systems.

Platinum catalysts are used in the petroleum industry for the production of high-octane gasoline. The platinum catalytic exhaust control system in automobiles requires lead-free gasoline because lead fouls the catalyst and destroys its effectiveness. To obtain a satisfactory octane rating in non-leaded or low-lead gasoline requires further reforming, and thereby increases the demand for platinum alloy catalysts used in the process. A platinum-rhenium catalyst has been found effective in this application, but a drawback to its use is the small potential supply of rhenium metal.

Platinum alloyed with other platinum group metals finds wide application as a catalyst in the chemical industry, an important application being in the production of nitric acid from the combination of ammonia and oxygen. The platinum metal catalysts are also used in the production of other industrial chemicals, pharmaceutical products and in the food processing industry.

The electrical industry is a major consumer of platinum. It is used in the electronic industry in printed circuits, alone and with other precious metals; in electrical furnaces, thermocouples and electrical contacts. Platinum is also used in the cathode protection of ships hulls. A major use of palladium is in electrical contacts for telephone equipment. The metal was used alone in this application, but the high price prevailing in 1974 led to the development of a palladium-silver alloy which has substantially reduced the consumption of palladium in this field.

A platinum-rhodium alloy is used in bushings and spinnerets in the production of fibre glass and synthetic fibres and in the glass manufacturing industry. The jewellery trade is a substantial consumer of platinum, especially in Japan.

Platinum metals are used in dental applications, laboratory equipment, in the field of medicine and medical research and in fuel cells for direct generation of electric current. Because of its resistance to corrosion at high temperatures, iridium crucibles are used for the growing of laser crystals and synthetic gems.

Prices

A slower-than-expected recovery in the industrial world's economy resulted in a comparatively stable price pattern for platinum, palladium, osmium and ruthenium. The price of rhodium increased substantially because of its expected use as a catalyst in automotive emission control and the producer price of iridium decreased sharply, although the dealer price was generally stable. Deliveries of platinum metals to the automobile and electric industry were up, but demand in the other major uses was weak.

Platinum. The producer price of platinum remained unchanged at $U.S. 155-165 an ounce from the beginning of 1976 to June 8, 1976. For the first four months of the year the dealer price of platinum averaged about $U.S. 12 an ounce below the producer price. The dealer price increased gradually after this period and by June 8 was about $U.S. 9 an ounce above the producer price. To bring the producer price in line with the dealer quotes, the major producers increased their price to $U.S. 165-175 an ounce on June 9. Speculative buying and an expected pickup in demand pushed the dealer price upward until it reached a high of $U.S. 179-180 an ounce on July 7. On July 6 Impala Platinum increased its price to $U.S. 170-180 an ounce and on July 16 Rustenberg increased its price to $U.S. 180-190 an ounce. Impala maintained its price at the lower level and did not follow the trend set by Rustenberg. The anticipated pick-up in demand for platinum did not develop and the dealer price declined. At year-end it was quoted in the area of $U.S. 150 an ounce. To lessen the price differential between the producers and dealers, the producers lowered their price to $U.S. 162-172 an ounce on November 15 and it remained at this level for the rest of the year.

Palladium. The U.S.S.R., as the major world supplier of palladium, plays an important role in determining the world price of this metal. Sales of precious metals by the U.S.S.R. are generally made to obtain foreign reserve assets to purchase wheat and capital equipment. Sales of palladium can be made to suit its needs, selling when the price is at a satisfactory level and withholding the metal from the market when the price is depressed, unless immediate funds are required. The producer price of palladium was $U.S. 50-55 an ounce until the end of March 1976 at which time it was lowered to $U.S. 40-45 an ounce to bring it more in line with the dealer price. The producer price was increased to $U.S. 45-50 an ounce on May 20 and the dealer price then moved upwards into this price range. With a firmer market for palladium, the producer price was increased to $U.S. 55-60 an ounce on June 23 and it remained unchanged at this level for the balance of the year. The dealer price varied above and below the producer price, but generally it remained close to the producer price.

Rhodium. The development of rhodium as part of a three-way catalyst in catalytic converters for use in Volvo automobiles to control emission pollutants, and the expectation that it will be introduced by other manufactures on their models, sparked a sharp rise in both the producer and dealer price of the metal. The producer price for rhodium remained unchanged from the beginning of 1976 to June 30 at a price of $U.S. 300-310 an ounce. On July 1 it was increased to $U.S. 350-360 an ounce on expectations of increased consumption, and on July 20 jumped to $U.S. 400-410 an ounce and remained at this level for the balance of the year. The dealer price varied considerably during 1976: from $U.S. 195-285 for the period from the beginning of the year to June 23, from $U.S. 316-375 for the period June 24 to July 7, from $U.S. 405-420 for the period July 8 to October 6 and from $U.S. 390-405 for the balance of the year.

Iridium. For the first three months of 1976 there was a wide divergence between the producer and dealer prices of iridium. At the beginning of the year the producer price was quoted at $U.S. 400-410 an ounce and the dealer price varied from a low of $U.S. 210 an ounce to a high of $U.S. 310, the low price prevailing in April. On April 1 the producer price was lowered to $U.S. 300-310 an ounce and it remained at this level for the balance of the year. The dealer price advanced from its low in April to a high of $U.S. 330-345 an ounce on August 5 and declined steadily from this high to the year's closing price of $U.S. 275-285 an ounce.

Osmium and Ruthenium. The producer prices for osmium and ruthenium remained unchanged for the year at $U.S. 200-225 an ounce and $U.S. 60-65 an ounce, respectively. The dealer price for osmium was stable during the year and was quoted at $U.S. 125-135 an ounce. The dealer price for ruthenium dropped sharply in the first part of 1976, from $U.S. 45-50 an ounce to a low of $U.S. 30-36 an ounce the middle of February. The price then firmed slightly from this low, probably on reports that ruthenium may be used in place of rhodium in catalytic converters, and in the latter part of the year was being quoted in the range of $U.S. 34.50- 40.00 an ounce.

Outlook

In the short-term view the supply of platinum group metals is expected to be more than adequate to meet demand. In the Republic of South Africa the mine operators can adjust their platinum metals output to meet world requirements because their ores are mined primarily for contained platinum metals. Such adjustments are not possible in Canada and the U.S.S.R. where platinum metals output is a function of nickel production. In 1975 the major South African producers of platinum metals reduced their annual rate of production by 25 per cent. A moderate increase in demand can be met by restoring part or all of this production cut-back. Expansion programs now under way to increase the annual rate of platinum metals output at South African mines are being implemented on a flexible basis and can be accelerated if the demand for these metals increases appreciably. However, there are no developments on the horizon that could substantially increase the demand for platinum metals.

Recycling plays an important role in the supply of platinum metals to the market. It is estimated that over 80 per cent of the platinum metals consumed by industry can be recycled. This is important to industrial consumers because it helps offset the generally high initial cost of materials containing platinum metals. In the United States, one of the few countries which keeps detailed statistical data on platinum metals, 6 750 kg were recovered from secondary sources in 1976. This does not include toll-refined secondary platinum metals estimated to be over 31 100 kg.

Platinum metals in the United States government stockpile at the end of 1976 were: platinum, 14 079 kg; palladium, 83 554 kg and iridium, 529 kg. In October 1976 the United States Federal Preparedness Agency announced a new stockpile program for platinum group metals. The new goals are: platinum, 40 870 kg; palladium, 76 204 kg and iridium, 3 041 kg; substantially above current inventory levels. Congressional authorization is required before any metal can be purchased to add to inventory. It is expected that if the program is approved, platinum metals added to the stockpile will be purchased over a comparatively long period of time in order not to unduly affect the market. This new stockpile policy, whether adopted or not, should ensure that no sales will be made from the present stockpile in the near future.

In the immediate future it appears that platinum metals catalytic converters will continue to be the best method of attaining the automotive emission standards established by the United States Environmental Protection Agency (EPA). Research projects on other methods to control automobile exhaust emissions have not reached the efficiency of the platinum metals catalytic converters. In the United States, the demand for platinum and palladium for use in the catalytic converters increased sharply in 1976 because of an upsurge in the automobile industry and was estimated at 20 622 kg. Under present technology, it should remain at or near this level for some time. The platinum metals required to meet this demand will come largely from primary production, but in a few years large amounts of platinum and palladium will appear on the market from recycled converters.

In April 1976 the EPA decided not to propose standards for controlling sulphur emissions from catalytic converters. Research has shown that the sulphur emission problem does not warrant federal standards. This decision will ensure the continued use of the platinum metals catalytic converters on automobiles for use in the United States.

An important development in 1976 was the announcement by AB Volvo Co. that it had successfully developed a platinum-rhodium catalyst which has been tested on 1977 four-cylinder prototype cars and reduced the nitrogen oxide pollutants from the emissions of these automobiles to acceptable levels. Most of the automobiles manufactured in the United States have six and eight cylinders, and it has not yet been determined if the above success can be duplicated on these larger vehicles. The United States car manufacturers are working on solutions to the problem of nitrogen emissions and if the final answer is the use of a platinum-rhodium catalyst, the mines of the Republic of South Africa should be able to meet the demand, especially if a catalyst is developed that contains the metals in nearly the same ratio as occurs in the ore deposits.

In view of surplus platinum production capacity, a major South African producer launched an aggressive advertising and promotion campaign in 1975 in Japan, the United States, the United Kingdom and West Germany to promote the use of platinum metals in the jewellery trade. The Japanese are the world's largest consumers of platinum and about 70 per cent (31 000 kg in 1976) of Japan's total consumption was consumed by the jewellery trade. This compares with about 3 per cent for the United States and about 7 per cent for Western Europe. It is evident that a large potential market exists for the use of platinum in jewellery manufacturing in these latter two countries, but it will take some time before the results of the promotion can be assessed. Platinum use in jewellery in the United States and Western Europe will be competing with gold, the traditional metal for jewellery in these countries. The recent downturn in the platinum-gold price ratio could encourage an increased use of platinum in jewellery.

The major consumer of palladium has been in the telecommunications field. The high price of palladium prevailing in 1974 led to the substitution of palladium in this field by an alloy containing 60 per cent palladium and 40 per cent silver, thus drastically reducing the consumption of palladium.

In the long-term outlook the consumption of platinum metals in the present applications should show a steady growth pattern. Because of their unique properties, research now being done to develop new uses for the platinum metals should meet with success. A new use for platinum could result from the successful industrial development of a fuel cell as a source of power in which a platinum-coated electrode acts as the catalyst for the direct conversion of chemical energy into electrical energy. The large reserves of platinum group metals contained in the Merensky Reef in the Republic of South Africa can be developed to keep supply in balance with demand. New nickel mines are being developed in the U.S.S.R. and the platinum metals recovered from treatment of the new nickel ores may have a significant impact on the platinum metals market.

United States prices of platinum group metals, 1976, as reported in Metals Week

	Producers	Dealers
	($U.S. per troy ounce)	
Indium		
January 1 — February 4	400.00 — 410.00	265.00 — 310.00
February 5 — March 31	400.00 — 410.00	215.00 — 255.00
April 1 — June 16	300.00 — 310.00	210.00 — 235.00
June 17 — July 7	300.00 — 310.00	235.00 — 275.00
July 8 — October 13	300.00 — 310.00	305.00 — 350.00
October 14 — December 31	300.00 — 310.00	275.00 — 310.00
Osmium		
January 1 — December 31	200.00 — 225.00	125.00 — 135.00
Palladium		
January 1 — February 11	50.00 — 55.00	39.00 — 44.00
February 12 — March 31	50.00 — 55.00	36.75 — 39.00
April 1 — May 19	40.00 — 45.00	37.50 — 42.00
May 20 — June 9	45.00 — 50.00	43.00 — 45.75
June 10 — June 22	45.00 — 50.00	51.25 — 53.00
June 23 — July 7	55.00 — 60.00	51.25 — 56.50
July 8 — July 21	55.00 — 60.00	59.50 — 61.50
July 22 — December 31	55.00 — 60.00	50.00 — 55.25
Platinum		
January 1 — April 7	155.00 — 165.00	136.00 — 147.00
April 8 — April 21	155.00 — 165.00	146.00 — 149.00
April 22 — June 2	155.00 — 165.00	154.50 — 160.00
June 3 — June 8	155.00 — 165.00	164.25 — 165.25
June 9 — June 30	165.00 — 175.00	164.50 — 170.50
July 1 — July 15	165.00 — 175.00	173.00 — 180.00
July 16 — July 21	170.00 — 190.00	175.00 — 176.00
July 22 — August 4	170.00 — 190.00	161.00 — 165.50
August 5 — September 22	170.00 — 190.00	155.00 — 160.00
September 23 — October 6	170.00 — 190.00	161.00 — 162.50
October 7 — October 31	170.00 — 190.00	156.00 — 159.00
November 1 — December 15	162.00 — 172.00	155.25 — 160.00
December 16 — December 31	162.00 — 172.00	147.75 — 151.50
Rhodium		
January 1 — February 11	300.00 — 310.00	215.00 — 230.00
February 12 — May 5	300.00 — 310.00	195.00 — 215.00
May 6 — June 9	300.00 — 310.00	210.00 — 235.00
June 10 — June 23	300.00 — 310.00	265.00 — 285.00
June 24 — June 30	300.00 — 310.00	316.00 — 327.00
July 1 — July 7	350.00 — 360.00	365.00 — 375.00
July 8 — July 15	350.00 — 360.00	414.00 — 420.00
July 16 — July 19	350.00 — 410.00	414.00 — 420.00
July 20 — October 6	400.00 — 410.00	405.00 — 420.00
October 7 — November 17	400.00 — 410.00	390.00 — 405.00
November 18 — December 31	400.00 — 410.00	380.00 — 395.00
Ruthenium		
January 1 — February 11	60.00 — 65.00	45.00 — 50.00
February 12 — March 3	60.00 — 65.00	30.00 — 36.00
March 4 — May 26	60.00 — 65.00	33.00 — 38.00
May 27 — December 31	60.00 — 65.00	34.25 — 40.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential*
36300-1	Platinum wire and platinum bars, strips, sheets or plates; platinum, palladium, iridium, osmium, ruthenium and rhodium, in lumps, ingots, powder, sponge or scrap	free	free	free	free
48900-1	Crucibles of platinum, rhodium and iridium and covers therefore	free	free	15%	free

*General Preferential Tariff rate from July 1, 1974 to June 30, 1984

United States

Item No.		Rate of Duty
601.39	Precious metals ores	free
605.02	Platinum metals, unwrought, not less than 90% platinum	free
		On and After Jan. 1, 1972
605.03	Other platinum metals, unwrought	20%
605.05	Alloys of platinum, semimanufactured, gold-plated	25%
605.06	Alloys of platinum, semimanufactured, silver-plated	12%
605.08	Other platinum metals, semimanufactured, including alloys of platinum	20%
644.60	Platinum leaf	20%

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division Ottawa; Tariff Schedules of the United States, Annotated (1976) TC Publication 749.

Potash

B.W. BOYD

In 1976 world production of potash reached 23 964 000 tonnes*, a decrease of 2 per cent from 1975 production. The greatest increases were evident in the Eastern Bloc countries, U.S.S.R. and East Germany, where efforts were directed at producing as close to capacity as possible. World consumption rose from 20 000 000 tonnes in 1975 to an estimated 22 000 000 tonnes in 1976, about 1 000 000 tonnes above the previous record level achieved in 1974. Customer preference for the coarse and granular grades of potash led to a fairly strong market for these grades, particularly in North America, while a decrease in demand resulted in substantial price discounting for standard-grade product.

The bulk of world potash production is in the form of potassium chloride (KCl), known in the industry as muriate of potash, and used in the production of fertilizer. All Canadian potash production is marketed as the chloride, with a potassium content of about 50 per cent (60-62 per cent K_2O equivalent). This product is marketed in the United States, in offshore countries and domestically in the percentage ratio of 77.9, 17.3 and 4.8 respectively. The high percentage of exports results in Canada's 36 per cent share of the international potash trade.

Production and developments in Canada

Saskatchewan. There are ten potash mines in Canada (all in the province of Saskatchewan) with an installed productive capacity of 12 920 000 tonnes of potassium chloride (7 837 000 tonnes K_2O equivalent). In 1975 the industry operated at 64 per cent of capacity because slack demand, especially in the offshore market, resulted in large inventories of product at the minesites.

Canadian production of 4 995 862 tonnes of potash in 1976 represents a decrease of 8.1 per cent from 1975 production; in the same period shipments increased by 11.5 per cent to 5 173 148 tons. The value of potash shipments totalled $361 442 000, an increase of 0.8 per cent over the value in 1975. The average realized price fell from $76.73 per tonne K_2O equivalent in 1975 to $69.87 per tonne in 1976. The Potash Institute of North America reports producer stocks at the end of 1976 at 799 007 tonnes.

There were no strikes during 1976 but producer inventories were so high early in 1976 that International Minerals & Chemical Corporation (Canada) Limited (IMC (Canada)) decided to close its K-2 mine for 6½ months. In September, when demand improved, K-2 was reopened. The only other major shutdown resulted from storm damage at the Alwinsal Potash of Canada Limited operation. One new labour contract was signed during 1976 covering members of the United Steelworkers Union at the Cominco Ltd. mine.

New Brunswick. Two companies were active in potash and salt exploration in New Brunswick during 1976. Potash Company of America, working on a lease granted in 1973, drilled 20 holes before suspending drilling in August 1976 and beginning development plans. In January the province issued a lease to IMCC for the exploration and development of potash and salt on a 200-square-kilometre tract. To date, ten holes have been drilled in addition to the original hole put down in a program funded by the provincial and federal governments. Intersections in seven of the first 11 holes graded about 29 per cent K_2O equivalent over an average thickness of 21 metres in an area 1 200 metres by 3 600 metres at depths of 600 to 1 000 metres.

Ontario. Shamrock Chemicals Limited's potassium sulphate plant at Port Stanley, Ontario is being rebuilt to produce 100 tonnes of product daily. Another group is planning to build a potassium sulphate plant in the same area to supply the tobacco farmers in Southern Ontario.

Government-industry relations

In January the Saskatchewan legislature passed Bill 1 and Bill 2 relating to takeover of potash mines by purchase or expropriation and confirming by statute

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois. Unless otherwise noted, potash tonnages are in tonnes of K_2O equivalent.

Table 4. Posted prices for muriate of potash

	Jan/76	Feb-Apr/76	May/76	June/76	July-Aug/76	Sep/76 Jan/77	Feb/77
	(dollars per tonne K_2O equivalent fob Saskatchewan)						
Standard 60-62	77	83	77	72	61	72	77
Coarse 60-62	80	86	80	75	69	80	86
Granular 60-62	83	88	83	77	72	83	88
Suspension 60-62	78	84		73	67	78	84

Source: Price schedules of various potash companies.
. . Not available.

Queen's Bench to set up a trust for reserve tax payments and guarantee return of the taxes if the reserve tax was declared *ultra vires*. The court did not set up the trust. The companies then attacked the bothersome provisions of the Proceedings Against the Crown Act and, on October 5, 1976, the Supreme Court of Canada ruled the provisions which would have prevented the province from refunding the taxes *ultra vires*.

In May 1976 nine companies approached the Reserve tax and proration fee problem from a different angle and took a case to the Court of Queen's Bench claiming that the two imposts were, in fact, royalties in breach of the contracts between the Saskatchewan government and the companies. The contracts guarantee no change from the royalties in place when the contracts were made (1960-1971) until 1981. The case is still before the court.

Table 5. Canada, potash production and trade, years ended June 30, 1967-76

	Production	Imports[1]	Exports
	(tonnes K_2O equivalent)		
1967	1 999 645	34 555	1 818 455
1968	2 695 433	29 846	2 470 691
1969	2 799 568	22 317	2 377 434
1970	3 565 837	24 512	3 309 758
1971	3 104 776	33 870[r]	3 011 204
1972	3 765 819	46 031	3 605 404
1973	3 623 917	73 591	3 528 341
1974	4 877 797	37 009	4 747 886
1975	5 063 635	28 764[r]	4 583 648
1976[p]	4 833 296	16 445	4 314 150

Source: Statistics Canada. 46-207 table 10
[1] Includes potassium chloride, potassium sulphate, except that contained in mixed fertilizers.
[p] Preliminary; [r] Revised.

Markets

About 95 per cent of the world's potash output is used for fertilizers, the balance being used for industrial purposes, including the manufacture of soaps, glass, ceramics, textiles, dyes, explosives and numerous chemicals.

Sales of potash in Canada totalled 248 840 tonnes in 1976, an increase of 9.3 per cent over sales in 1975. Of the material sold, 78.0 per cent was coarse grade and most of the remainder was granular. Imports of potassium magnesium sulphate and potassium sulphate increased by 3.8 per cent to 14 120 tonnes. Ontario and Quebec were the largest domestic consumers of all grades of potash and together accounted for 79 per cent of Canadian sales.

Sales of Canadian potash in the United States totalled 4 029 298 tonnes, an increase of 26.6 per cent over sales in 1975. Coarse, granular and standard grade product for agricultural use was sold in the ratio 44.0 to 29.8 to 14.6, while chemical and soluble grades made up the remaining 11.6 per cent.

Table 6. Canada, consumption of potash fertilizers, years ended June 30, 1967-76

	In Materials	In Mixtures	Total
	(tonnes K_2O equivalent)		
1967	25 225	136 383	161 608
1968	31 544	134 561	166 105
1969	37 165	131 142	168 307
1970	36 718	137 896	174 614
1971	42 484	141 849	184 333
1972	43 853	205 075	248 929
1973	41 707	149 001	190 708
1974	44 334	157 705	202 039
1975	62 945	143 867	206 813
1976[p]	84 649	157 428	242 077

Source: Statistics Canada. 46-207 table 8
[p] Preliminary.

The six states consuming the most potash; Illinois, Iowa, Indiana, Ohio, Minnesota and Georgia, are supplied chiefly from Canada, as are eight of the 12 other major potash-consuming states (over 100 000 tonnes K_2O equivalent each, annually). The portion of the market not served by Canada is supplied from potash mines in New Mexico, Utah and California, and by imports, mainly from Israel.

Consumers in the northern states (Canada's main market) showed a preference for the coarse and granular grade products, which led to buildups of standard product in the producers' stockpiles. In response, the normal three-dollar-a-tonne price spread between standard and coarse material increased during the fall until it reached nine dollars for deliveries in February 1977.

Offshore sales of Canadian potash fell by 27 per

Table 7. Canada, potash deliveries by product and area, 1975-76

		Agricultural							Industrial
		Potassium Chloride					Potassium		
		Standard	Coarse	Granular	Soluble	Potassium Sulphate	Magnesium Sulphate	Total Agricultural	
		(tonnes K_2O equivalent)							
Alberta	1975	830	1 557	2 211	1 107	23	91	5 819	3 379
	1976	1 069	1 715	5 227	1 936	23	41	10 011	5 525
British Columbia	1975	—	4 753	264	54	226	188	5 485	162
	1976	57	3 275	1 952	57	220	192	5 753	200
Manitoba	1975	81	1 243	802	11	—	23	2 160	194
	1976	—	1 004	1 989	24	23	73	3 113	75
New Brunswick	1975	276	8 302	—	—	23	286	8 887	—
	1976	—	10 210	160	—	45	518	10 933	—
Northwest Territories	1975	—	—	—	—	—	—	—	817
	1976	—	—	—	—	—	—	—	908
Nova Scotia	1975	89	4 005	—	—	—	30	4 124	—
	1976	—	5 222	55	—	34	23	5 334	—
Ontario	1975	1 128	108 669	888	323	5 573	3 967	120 548	4 835
	1976	1 251	115 263	7 838	836	5 287	2 871	133 346	3 893
Prince Edward Island	1975	—	7 772	—	—	73	45	7 890	—
	1976	—	8 568	—	—	285	432	9 285	—
Quebec	1975	4 728	54 971	(−55)	—	1 335	1 722	62 701	133
	1976	4 381	48 667	2 847	—	1 569	2 483	59 947	23
Saskatchewan	1975	44	285	114	—	—	—	443	186
	1976	13	117	62	257	—	1	450	44
Totals	1975	7 176	191 557	4 224	1 495	7 253	6 352	218 057	9 706
	1976	6 771	194 041	20 130	3 110	7 486	6 634	238 172	10 668

Source: Potash Institute of North America.
— Nil.

cent in 1976 with the notable losses of the market in the People's Republic of China and a large part of the Japanese market. The depressed offshore market affected the sales of standard grade material and was partly responsible for the buildup of standard material in producers' stockpiles.

Until 1976 an industry marketing organization, Canpotex Limited, handled all offshore exports of Canadian potash. During 1976 Potash Company of America, PPG Industries Canada Ltd. and AMAX, Inc. applied to leave Canpotex. The Potash Corporation of Saskatchewan Sales Limited was accepted as a new member, replacing Duval Corporation of Canada in the Canpotex organization. Among the important sales during the year was a Canpotex Limited contract to ship 360 000 tonnes K_2O equivalent to the Namhae Chemical Company of South Korea over a four-year period beginning in 1977.

Imports of potassium chloride into eastern Canada remained very low at 4 199 tonnes KCl, well below the peak reached in 1972 when 62 718 tonnes were shipped from the United States. Imports of potassium sulphate were reduced to 7 831 tonnes K_2SO_4 and imports of potash fertilizers other than KCl or K_2SO_4 increased by 676 tonnes to total 45 134 tonnes. Imports of potassium chemicals totalled 10 973 tonnes, a decrease of 2 625 tonnes from the amount imported in 1975.

Prices

Price lists published in 1976 gave an average price of about $85 a tonne for potash for delivery in February, 1977, but few sales were made at that price. Discounting brought the average realized price down to about $75 per tonne for the spring season. This reduction was reflected in published prices for May and June, and then producers posted lower prices for July and August. The realized prices for July to September averaged about $60 a tonne, $10 below posted prices and $15 below the price in January 1976.

Sales at the low price levels were very good and prices recovered to average about $67 in the final quarter of the year.

External developments

Several matters were initiated in the United States which pertained to the potash industry in Saskatchewan. In December 1975 the United States Embassy in Canada delivered an aide-memoire expressing concern about the proposed takeover by Saskatchewan of some of the potash mines operating in the province. The Canadian response, delivered in March 1976, quoted the province's intention to continue to supply potash at market prices and outlined the provincial legislation on takeovers, which meets internationally-accepted criteria for compensation. A United States Senate Resolution expressing concerns similar to those in the aide-memoire did not lead to further action.

On June 29, 1976 an indictment was filed in the United States District Court, Northern District of Illinois, charging six U.S. companies, and subsidiaries of two of the companies, with conspiracy to restrain inter-state and foreign trade and commerce by restricting production, export and import of potassium chloride, and by price-fixing. In August, 157 persons and corporations were named as co-conspirators but were not charged. Because the case relates to the prorationing system operated in the Saskatchewan potash industry from 1970 to 1974 a large number of Canadians were among those named as unindicted co-conspirators. The case comes to trial in January 1977. The State of Illinois, as a follow-up to the Grand Jury investigation, has filed a suit demanding treble damages for the higher prices paid for potash during prorationing.

World review

Potash is used chiefly in mixed fertilizers, along with ammonia and phosphate compounds. In the past three years the price of ammonia has increased steadily with the increasing cost of natural gas. In the 1974 to 1975 period the price of phosphate rock quintupled. As a result, the world price of fertilizer products increased three-fold and farmers could not afford to buy as much fertilizer as in the past. In 1976 the price of phosphate rock fell from the high in 1975 to about double the 1973 price and demand for fertilizer recovered somewhat from the low level of 1975. Potash demand increased by less than 10 per cent and did not reach the level of consumption reported for 1974.

The world's largest producer of potash, Russia, has become the world's largest consumer of potash. The key factors in this development were the increased production of KCl and improvements in the transportation of fertilizers within the U.S.S.R. The U.S.S.R. has also been up-grading its muriate of potash for export and can now produce coarse material which approaches North American specifications.

There are current agreements and negotiations between Soyuzpromexport of the U.S.S.R. and United States companies for the sale and barter of 2 000 000 tonnes of muriate of potash a year. The U.S. companies could sell the potash in North America or elsewhere in the world.

In the United Kingdom, the new potash mine at Boulby was operating at about one-half of rated capacity because of production difficulties.

In the United States, National Potash Company closed its Eddy County mine at the end of the year and rationalized production at its Lea County mine. Mississippi Chemical Corporation shut down its mine in New Mexico for part of the year during renovations leading to more efficient production.

The development of recovery methods for ore previously assumed to be unavailable to second-mining techniques, and proving of extensions to the known deposit have increased the reserve estimates for the

Ideal Basic Industries, Inc.'s mine in Carlsbad, New Mexico. The new reserves are expected to extend the remaining life of the mine for 11 years and it is probable that similar reserve re-evaluations for other mines in Carlsbad will be forthcoming, and mining could continue there for several decades.

Exploration is proceeding in at least two areas of the world as PPG Industries, Inc. and CF Industries, Inc. drill for potash in Montana and North Dakota in the United States, and the Thai government drills discoveries near the Thailand-Laos border.

Outlook

Demand for potash in 1977 is expected to return to the levels corresponding to a long-term growth rate of about 5 per cent a year. For Canada this means that sales should approach 7 000 000 tonnes a year if our share of the international market can be maintained.

Developing countries more and more are demanding coarse and granular material. If Canadian companies expand their compacting capacity they will be able to increase their share of the international market over the next few years. In the 1980s new production capacity will be needed if Canada is to benefit from the forecast growth in demand. Expansion of the industry must be initiated now to meet the expected demand of 1980.

Production levels are expected to continue increasing in the U.S.S.R. and construction is under way on plants to raise the quality of the product for export to 60 per cent K_2O, and coarse grade. These developments will put the U.S.S.R. in a very strong position in the world potash market.

Table 8. World potash production, sales and inventories 1974-76

	1974		1975		1976p	
	Production	Sales	Production	Sales	Production	Sales
	(thousand tonnes K_2O equivalent)					
U.S.S.R.	6 586	6 373	7 944	7 600	8 250	. .
Canada	5 480	5 778	5 436	4 638	4 996	5 173
East Germany	2 864	2 863	3 019	3 016	3 200	. .
United States	2 326	2 312	2 294	1 891	2 205	2 253
West Germany	2 620	2 652	2 222	2 130	2 036	. .
France	2 083	2 126	1 920	1 800[1]	1 603	. .
Israel	607	1 100	716	. .	700	. .
Spain	396	. .	459	368	535	. .
Congo	285	279	286	. .[1]	254	. .
Italy	151	. .	141	. .	140	. .
United Kingdom	11	. .	15	. .	45	. .
Other countries	—	61	—	695	—	. .
Total	23 409	23 544	24 452	22 138	23 964	. .

Year-end producer inventories

	1974	1975	1976p
Canada	120	990	799
United States	186	574	475

Sources: Potash Institute of North America, and *Phosphorus and Potassium.*
[1] 1975 France sales figure includes sales from Congo.
pPreliminary; — Nil; . . Not available.

Rare Earths

G.E. WOOD

The rare earth elements, sometimes called the lanthanons or lanthanides, are a group of 15 chemically similar metals having atomic numbers 57 to 71 in Group III of the periodic table of elements. Scandium and yttrium are similar to the rare earth elements in many respects and are usually classed with them.

These elements are neither rare nor earths. By comparison, cerium is more abundant than tin or cobalt and almost three times as abundant as lead. Thulium, less common than all other rare earths except promethium, is more abundant than silver, gold and platinum combined. The metals were originally classified "rare" because they are seldom concentrated in nature like most other elements and their widespread occurrence in the earth's crust was recognized only in recent times. The term "earth" is derived from earlier terminology when insoluble oxides, the common compounds of rare earths, were simply referred to as earths.

Lanthanon-bearing minerals contain all members of the rare earth elements, but either the light (cerium) group or the heavy (yttrium) group predominates in each mineral. The rare earth metals are typically associated with alkaline complexes and pegmatites, and secondary concentration can occur in placer, beach sand, and phosphatic sedimentary deposits. Commercial production has been derived from carbonatite occurrences, placer, and beach sand deposits, uranium ores and phosphatic rocks. The relative abundance of the various rare earths in the ores presently being mined is not directly related to the market demand for the individual products. As a result, some rare earths products are readily available at low cost, while others, particularly high-purity metal and compounds, are considerably more expensive. Research continues to explore the properties of the rare earth metals to identify potential new markets but, for some, no significant use has yet been found. Development has proceeded; first, to find markets for those compounds that are available and, second, to find and develop sources of supply to meet changing industrial requirements.

New uses have developed steadily in recent years. Beginning with the traditional cigarette lighter flints and carbon-arc uses, rare earth elements have now found application in glass polishing, petroleum catalysts, television tube phosphor, nodular iron, high-strength, low-alloy steel and high-strength magnet applications. The latest uses of rare earth elements are at the forefront of technological development, in refractory ceramics, lighting, data storage and in the energy field.

Canadian production of rare earths since 1967 has undergone drastic adjustments; yttrium concentrate suppliers reduced shipments each successive year until 1971, when deliveries stopped. Shipments of yttrium concentrate from one Canadian producer, Denison Mines Limited, were resumed in 1973 and continued in 1974, 1975 and 1976.

New markets for specific members of the rare earth group have resulted in increased production of all rare earth metals because of their natural association in ores. Similarly, production costs for some rare earth members, byproducts of the refining process, have diminished. Availability and declining costs have been important factors in the development of new uses. There is growing optimism that the rare earth metals industry will expand at a steady rate now that industrial uses are becoming more diverse.

Canadian industry

From 1966 to 1970 the world's major source of yttrium concentrate was the uranium mines in the Elliot Lake district of Ontario. All rare earths, except promethium, have been detected in these ores. The Elliot Lake ores contain about 0.11 per cent uranium oxide (U_3O_8), 0.028 per cent thorium oxide (ThO_2) and 0.057 per cent rare earth oxides (REO).

Denison Mines Limited (Denison), which resumed the production and shipment of yttrium concentrate in 1973, continued to produce in 1976. Under a contract negotiated with a United States company, Molycorp Inc. (Molycorp), Denison has a commitment to ship yttrium concentrate to Molycorp until March 1977. Denison had previously shipped yttrium concentrate to Michigan Chemical Corporation, but production was

Table 1. Rare earth elements

Atomic No.	Name	Symbol	Abundance in Igneous Rocks
	Light rare earths		(parts per million)
21	Scandium	Sc	5.0
57	Lanthanum	La	18.3
58	Cerium	Ce	46.0
59	Praseodymium	Pr	5.5
60	Neodymium	Nd	23.8
61	Promethium	Pm	(Not measurable)
62	Samarium	Sm	6.5
63	Europium	Eu	1.1
64	Gadolinium	Gd	6.3
	Heavy rare earths		
39	Yttrium	Y	28.0
65	Terbium	Tb	0.9
66	Dysprosium	Dy	4.5
67	Holmium	Ho	1.1
68	Erbium	Er	2.5
69	Thulium	Tm	0.2
70	Ytterbium	Yb	2.6
71	Lutetium	Lu	0.7
		Total	153.0

Table 2. Canadian shipments of rare earth concentrates

	Y_2O_3 in Concentrates	Values
	(kilogram)	($)
1976[1]	26 308	..
1975[1]	34 927	..
1974	39 366	..
1973	..	..
1972	—	—
1971	..	..
1970	33 112	657 000
1969	38 756	671 500
1968	51 406	9 36 067
1967	78 268	1 594 298
1966	9 400	130 223

.. Not available; — Nil.
[1]Taken from Annual Reports, Denison Mines Limited.

terminated in mid-1970 when that company experienced difficulty in marketing the product. Denison shipped some concentrate in 1971, but the quantity and value was not reported.

During 1966 and 1967 Rio Algom Limited recovered thorium and rare earth concentrate at its Nordic mill, but did not resume production when the milling of uranium ores was transferred to the Quirke mill.

Rare earth elements, primarily the light element group, are associated with apatite in the Nemegos No. 6 magnetite deposit, which is located in the Chapleau area of Ontario. Multi-Minerals Limited is seeking to develop the deposit, and was trying at last report in 1975 to determine the feasibility of promoting an integrated complex which would produce pig iron, phosphoric acid and rare earth products.

In addition to the large reserves in Elliot Lake uranium ores, rare earths are also associated with uranium deposits at Agnew Lake, 65 kilometres east of Elliot Lake, where the REO content is about twice that of Elliot Lake ores; and in the Bancroft area of Ontario.

Kerr Addison Mines Limited decided in March 1976 to bring its 90 per cent-owned Agnew Lake uranium property into production. Initial production of U_3O_8 in concentrate by an underground leaching method is expected to begin during the second quarter of 1977. The Agnew Lake orebody has a relatively high content of rare earth metals associated with the uranium. The leach solution contains, in addition to uranium, substantial amounts of thorium, lanthanum, yttrium, cerium, gladolinium, dysprosium, erbium, ytterbium. None of the Agnew Lake rare earths are presently being recovered.

Phosphorite formations in western Canada contain small quantities of rare earths, as do Florida phosphates imported into Canada for the production of phosphoric acid. Other potential sources include apatite rich carbonatites.

Shipments of rare earth concentrates since 1966 are summarized in Table 2. Statistics for 1971 and 1973 have been withheld to avoid disclosing individual company confidential data.

Denison Mines Limited, the only Canadian producer of rare earth metals in 1976, reported to its shareholders that it produced 34 927 kilograms of yttrium oxide in 1975 and 26 308 kilograms in 1976.

World industry

The minerals monazite and bastnaesite are the main source of the cerium group of rare earths. These are processed to recover mixed rare earths for low-value products such as mischmetal, or further processed at much higher cost to separate individual rare earth metals.

Monazite recovery is a byproduct of mining beach sands for rutile, zircon and ilmenite. Australia, India, Brazil, Malaysia and the United States, soon to be

Table 3. Principal world processors of rare earth ores and concentrates

Austria
  Treibacher Chemische Werke Aktiengesellschaft
Belgium
  S.A. de Pont-Brûlé
Brazil
  Commissao National de Energia Nuclear (Industrias Quimicas Reunidas)
Britain
  British Flint and Cerium Manufacturers Limited
  British Rare Earths Limited
  London and Scandinavian Metallurgical Company
  Rare Earth Products Limited (a Thorium Ltd. and Johnson Matthey Chemicals Limited joint venture)
Finland
  Kemira Oy
France
  Rhône-Poulenc, Etablissements Tricot
West Germany
  Otavi Minen und Eisbahn Ges
  Th. Goldschmidt A.G.
India
  Indian Rare Earths Limited
Japan
  Ogino Chemical Company
  Nippon Yttrium Company
  Santoku Metal Industry Company
  Shin-Etsu Chemical Industry Company
  Wako Bussan Company
Norway
  A/S Metal Extractor Group of Norway (Megon)
United States
  American Potash and Chemical Corporation
  Lindsay Rare Earth Division[1]
  Michigan Chemical Corporation
  Molycorp Inc.
  Nucor Corp., Research Chemicals Division
  Rare Earth Metal Company of America
  Reaction Metals Inc., a subsidiary of Rare Earth Industries, Inc.
  Ronson Metals Corporation, Cerium Metals & Alloys Division
  W.R. Grace and Company, Davison Chemical Division
  Gallard-Schlesinger Chemical Manufacturing Corp., Atomergic Chemetals Co. Division
  Transelco, Inc.
U.S.S.R.
  State controlled. Output is sold through Techsnabexport

[1]The company's processing facilities located in West Chicago were closed in 1973.

joined by South Africa, are the principal producers. In the United States, monazite is recovered from beach sands in Georgia and Florida.

The Molycorp mine at Mountain Pass, California, is the main source of concentrates for cerium-group rare earths and, unlike monazite, bastnaesite concentrates from this unusual deposit in carbonatite do not contain thorium. The ore, mined in a small, low-cost open pit, grades 8 to 10 per cent rare earth oxides. The rare earth distribution, in per cent oxide, is: cerium, 50.0; lanthanum, 33.0; neodymium, 12.0; praseodymium; 4.0; samarium, 0.5; gadolinium, 0.2; europium, 0.1 and yttrium group, 0.2. The adjacent mill produces a flotation concentrate grading 60 per cent rare earth oxide, a leached concentrate grading 70 per cent, a calcine grading 90 per cent, and seven modified concentrates. A chemical and solvent extraction plant makes intermediate rare earth products and separates a number of rare earths, including europium. Further processing is carried out at Louviers, Colorado; York, Pennsylvania and Washington, Pennsylvania.

Production from the Mountain Pass mine in 1976 amounted to 13 200 tonnes* of REO, compared with 15 000 tonnes in 1975. Demand was reported to be sluggish early in the year, but improved as the year progressed. The Mountain Pass mill can now produce approximately 27 200 tonnes of REO annually and the chemical plant can process 13 600 tonnes.

A former Australian rare earth metals producer resumed production in 1976. The mine, operated by Mary Kathleen Uranium Limited, produced uranium and a rare earth concentrate until 1963. Total reserves at the mine, including tailings, contain some 363 000 tonnes of REO. At a planned annual mining rate of 816 000 tonnes of ore, the mine could recover about 4 500 tonnes a year of REO contained in concentrate.

Mitsubishi Chemical Industries Ltd. of Japan and Beh Minerals Sendirian Berhad of Ipoh, Perak State, Malaysia have set up a joint company, Malaysian Rare Earth Corp. (MAREC), to produce rare earths oxides containing a minimum of 60 per cent yttrium oxide from Malaysian xenotime. About 60 per cent of production, initially 9 tonnes a month, will be exported, mainly to Japan.

Japanese demand for REO has increased greatly in recent years. Molycorp has made an agreement with Mitsubishi International, Inc. whereby the latter company will act as sales agent for Molycorp's REO sales in Japan.

Following the completion of its full-scale facility for the production of high-purity yttrium oxide, A/S Megon & Co., (Megon), is now participating in a joint venture with Malaysian interests to construct and operate a concentrator near Kuala Lumpur in Malaysia. The plant has a design capacity of 27 tonnes a year of 60 per cent Y_2O_3 concentrate.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

The mineral xenotime, valuable for its yttrium content, is recovered from heavy mineral rejects of the Malaysian tin industry and from retreatment of Western Australian monazite concentrate, itself a byproduct.

Some uranium ores contain the rare earth elements and are an important source for the yttrium group. Solution liquors, following uranium and thorium extraction, are treated to recover the rare earth elements. Canadian production, and potential production in Australia from the Mary Kathleen Uranium Limited and Field Metals and Chemicals Pty. Limited deposits, are of this type. The rare earth minerals euxinite, samarskite and fergusonite are another source of the yttrium group, but they are difficult to treat.

Promethium isotopes have half-lives ranging from seconds to 18 years and, therefore, are rare in nature. The commercial source of promethium 147 is from waste fission products in atomic reactors. Its radioactive properties are attractive as a power source in space research as well as in luminescent paints.

Consumption and uses

World consumption of rare earth metals increased marginally in 1976. In the United States, leading applications of rare earth materials were in catalysts used in petroleum refining, as additives in steel and nodular iron, carbon arc electrodes, ceramics and glass, in lighter flints and in colour television phosphors. Use of rare earth metals in permanent magnets increased further in 1976.

Mischmetal is a suitable nodulizing alloy that promotes ductility in cast iron by neutralizing the harmful effects of trace elements which inhibit the formation of nodular graphite. The ductile iron industry has realized significant cost savings through the substitution of mischmetal for more expensive additives.

Mischmetal, the primary commercial form of mixed rare earth metals, is prepared by the electrolysis of fused rare earth chloride mixtures. Mischmetal contains 94 to 99 per cent rare earth metals plus traces of calcium, carbon, aluminum, silicon and iron. A typical composition is 52 per cent cerium, 18 per cent neodymium, 5 per cent praseodymium, 1 per cent samarium, 24 per cent others, including lanthanum. Some grades are nearly free of cerium. Ferrocerium is an alloy of mischmetal and iron.

In recent years the practice of adding some 1.5 kilograms of mischmetal or rare earth silicides to each tonne of high-strength low-alloy (HSLA) steels has become general to counter the deleterious effects of sulphur. The conventional method of treating undesirable sulphur is to combine it with magnesium, but magnesium sulphide elongates when rolled and the resulting steel is weaker in the transverse direction. The addition of rare earths results in a HSLA steel that is nearly equally strong in the transverse and longitudinal directions. HSLA steels are being used increasingly in gas and oil pipelines, automobiles, trucks, trains, ships, and construction equipment. Mischmetal has a stable market in lighter flints. However, the lighter flint market is becoming a less important outlet as mischmetal applications grow in the iron and steel metallurgical fields.

The other major use of the rare earth group is for catalysts in the cracking operation of petroleum refining. Although naturally mixed elements were originally used in catalysts, the trend has been to chloride mixtures of lanthanum, neodymium and praseodymium. Relative consumption in this field has been declining in recent years. Palladium is a substitute for the rare earth elements in petroleum-refining catalysts.

The third most important market for rare earth metals, in terms of volume, is the glass polishing industry. Commercial-grade cerium and mixed rare earth oxides are used extensively in optical, mirror and plate glass polishing. Plate glass polishing has been reduced since the introduction of the Pilkington float glass process, but there is no comparable substitute for rare earth oxide compounds in high-quality optical polishing.

The glass industry employs rare earth additives for their many unique characteristics. Cerium oxide, in small quantities, is an effective glass decolourizer. Due to their ability to absorb ultra-violet light, cerium and neodymium oxides are used in transparent bottles to inhibit food spoilage, and in welders' goggles, sunglasses and optical filters. For glass colouring, praseodymium imparts a yellow-green colour, neodymium a lilac, europium an orange-red, and erbium a pink colour. Lanthanum is a major component of optical glass, and cerium glass is used for windows in atomic reactors.

Rare earth oxides and fluorides are used in significant quantities in carbon-arc lamps where a high-intensity white light is desirable.

A new type of fluorescent lamp is now on the market which emphasizes three narrow spectral bands, around the blue-violet, green and orange-red wavelengths to produce a synthesized white light. This new light has a greater "perceived brightness" than even natural sunlight and permits a reduction in the number of lighting units in buildings. The new light uses two rare earth phosphors containing europium.

A high-value application is in the electronics field where rare earth oxides are used as phosphors in colour television tubes, temperature-compensating capacitors and associated circuit components. Although the volume of europium and yttrium oxides used in colour television phosphors is comparatively small, the value is disproportionately large because of the high degree of purity required in this application. Minor quantities of the rare earth group are used in laser materials, atomic fire extinguishers, nuclear reactor absorption and shielding materials, magnesium and aluminum alloys, brazing alloys, low-corrosion alloys, gemstones, self-cleaning oven catalysts, ceramic and porcelain stains and microwave controls.

An important and growing market is rare earth-cobalt permanent magnets (RE magnets). Samarium-cobalt permanent magnets are now in use that have many times the strength of any conventional permanent magnet. These magnets are usually fabricated by powder metallurgical methods, which facilitate the procedure for inducing a high magnetic flux. High-strength permanent magnets are used in special applications, such as aerospace equipment, where the greater cost can be justified in terms of better performance. Recent research has led to the development of less-expensive RE magnets. Part of this improvement has resulted from better manufacturing techniques, but a more significant development is the substitutions of mischmetal for some more-expensive samarium in magnets. Considering all the developments that have occurred within the few years since RE magnets were first discovered, the trend indicates a strong growth rate in use of these magnets for the next several years in electric motors, generators, meters, speakers and frictionless bearings. United States automobile manufacturers are seriously studying the application of mischmetal-cobalt magnets, in a range of sizes, for use in fuel gauges, electronic ignition systems, windshield wipers, window and seat drives, starter motors and in new developments such as continuous monitoring of tire pressures. Full realization of these potential uses will depend upon further cost and weight reduction, assured availability of cobalt and utilization of rare earth metals other than samarium.

Rare earth metals catalysts have been identified as possible inexpensive alternatives to platinoid catalysts in automobile exhaust converters. The rare earth-based converters have shown promise in reducing carbon monoxide and nitrogen oxide emissions, but more research is necessary. Initially, the automotive industry opted for platinum-based systems to meet emission control standards set for United States vehicles in 1975.

Research on rare earth metals uses has taken many directions and some very promising developments have resulted. "Hydrogen sponge" alloys have been developed which consist of nickel, and in some cases manganese, in combination with rare earth metals. These alloys can absorb up to 400 times their own volume of hydrogen gas. One cubic foot of these alloys can hold enough hydrogen to generate over 4 kilowatt-hours of heat energy. The ease with which the absorption process can be reversed, by a relatively small change in temperature or pressure, the selectivity of the process to hydrogen gas and the convenient temperature and pressure ranges over which it can occur are keys to its usefulness. Potential applications are in solar heating, non-polluting engines, heat sinks, gas purification and compression, and auxiliary power generation.

The development of memory films for use in "magnetic-bubble-memory" for data storage and processing promises to become a major new application for rare earth materials. Gadolinium-gallium garnet (GGG) has been found to be suitable for the production of precision wafers for these memory films. This new storage medium permits faster information handling, with fewer moving parts and lower energy use and greater storage capacity. It also decreases vulnerability to the effects of power loss. GGG bubble-memory storage capacity is claimed to be competitive already in terms of cost-per-bit of information with other storage media presently in use.

Yttrium is receiving attention from researchers for use in refractory ceramics for use in gas turbines, combustion chambers, nuclear reactors and heat exchangers.

Prices

The December issue of *Industrial Minerals* (London) quotes 70 per cent leach bastnaesite concentrates, per pound REO at 58-80 cents; Australian monazite, minimum 55 per cent REO, a long ton fob Australia, $A 165-175; Malayan xenotime concentrate, minimum 25 per cent Y_2O_3 a pound cif $U.S. 2-3.

The prices per pound in U.S. dollars of pure rare earth metals of the lanthanide group as used in permanent magnets, at year-end were as follows: lanthanum, $25.00; cerium, $18.00; samarium, $69.00; mischmetal, 99.8%, $3.45; mischmetal (no Ce), $12.00.

Rare earth oxide prices, in U.S. dollars per pound, as quoted in *American Metal Market,* 23 December 1976 issue were as follows: europium 99.99%, $540-600; lanthanum 99.9%, $6.00; cerium 99.9%, $6.00; neodymium 99.9%, $20.00-$25.00; praseodymium 99%, $30; yttrium 99.99%, $33-$36; gladolinium 99.9%, $52-55; samarium 99.9%; $35.

Rhenium

J.J. HOGAN

Rhenium is a relatively new metal which was first isolated in 1925. It occurs principally in low-grade porphyry copper ores containing molybdenum and is recovered as a byproduct from the treatment of molybdenum concentrates. The rhenium content in porphyry copper ore is only a few parts per million (ppm) whereas the molybdenite concentrates produced from these ores have a rhenium content varying from 300 to 2 000 ppm. Rhenium has been identified in some molybdenum, manganese and uranium ores, but in concentrations too low to be of economic significance under present technology and price structure.

Canadian rhenium production comes from the copper-molybdenum ore of Utah Mines Ltd. (Island Copper mine) at Port Hardy, Vancouver Island, British Columbia. The ore occurs mainly in altered volcanics and, in this respect, differs from the porphyry copper deposits which have been the major source of rhenium in the United States and Chile. The metal has also been identified in the porphyry copper ores of Lornex Mining Corporation Ltd. and Brenda Mines Ltd., near Kamloops, British Columbia.

The United States, the largest producer of rhenium metal and salts in the non-communist world, recovered rhenium mainly from porphyry copper ores in the western states. The producers of rhenium in the United States in 1976 were S.W. Shattuck Chemical Co., of Denver, Colorado, a division of Engelhard Minerals & Chemicals Corporation; M & R Refractory Metals, Inc. of Winslow, New Jersey, and Molycorp Inc. of Washington, Pennsylvania. Kennecott Copper Corporation did not operate its rhenium recovery facilities at Garfield, Utah.

Chile recovered rhenium from molybdenite concentrates produced as a byproduct from its large porphyry copper ore deposits. According to data published by the United States Bureau of Mines, the United States, during 1976, imported into bonded warehouses substantial quantities of ammonium perrhenate (NH_4ReO_4) from Chile. In 1974 Chile began exporting ammonium perrhenate to the United States. It is used in this form by industry or it can be further processed to rhenium powder. In previous years, rhenium exported to the United States was contained in molybdenite concentrates shipped there for treatment.

Other countries which have metallurgical plants to recover rhenium are the U.S.S.R., Sweden, Belgium, Holland and West Germany. With the exception of the U.S.S.R., these countries recover rhenium from molybdenite concentrates imported from Chile, Peru, Canada and Zaire.

Production

Rhenium is a recent addition to the metals produced in Canada, with production first being recorded in 1972. Utah Mines reported that the rhenium contained in the molybdenite concentrates produced in 1976 at its Island Copper Mine varied between 900 and 1 500 ppm and averaged about 1 172 ppm. This compares with an average of about 1 281 ppm in 1975. In 1976 shipments of molybdenite concentrates to refineries in the United States and Western Europe totalled approximately 2 145 tonnes* compared with 1 485 tonnes in 1975. The rhenium contained in the concentrates shipped by Utah Mines was treated on a toll basis at the receiving smelters and the recovered rhenium was returned to the company as perrhenic acid for subsequent sale. Under present technology the recovery of rhenium contained in molybdenite concentrates is in the range of 50 to 60 per cent. Based on the above shipments and estimated recovery and grade, the rhenium recovered from Canadian ores in 1976 was in the order of 1 250 kilograms.**

Statistical data on world output and total value of rhenium are not available. Rhenium production in the United States was estimated at 1 360.8 kilograms (kg) in 1976 by the U.S. Bureau of Mines compared with 907.2 kg in 1975. The value of United States production in 1976 was estimated at $1.5 million. Chile is

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.
**1 kilogram equals 2.2046 pounds avoirdupois.

believed to be the next-largest producer, and the U.S. Bureau of Mines estimated its 1976 output at 1 270.1 kg. The U.S.S.R., also a large producer of the metal, recovers rhenium from molybdenite concentrates obtained from its porphyry copper deposits, and its production in 1976 was estimated at 907.2 kg by the U.S. Bureau of Mines.

Rhenium is recovered from flue gases emitted from the roasting of byproduct molybdenite concentrates. Under properly controlled temperature conditions rhenium volatilizes as rhenium heptoxide (Re_2O_7) which is readily soluble in an aqueous solution. Flue-dust particles carrying about 10 per cent of the rhenium contained in the roaster feed are recycled to the roaster. Before flue-gas technology was developed, flue dust was the major source of the metal. To extract the rhenium, flue gases are cleaned of dust particles and wet-scrubbed to dissolve the rhenium oxide. The rhenium-bearing solution is conditioned for ion exchange treatment by the addition of certain chemicals to remove impurities. The solution is clarified, and the rhenium is absorbed on an ion exchange resin. Further hydrometallurgical steps are carried out until a high-purity ammonium perrhenate (NH_4ReO_4) is produced. Perrhenic acid ($HReO_4$) is obtained by the reaction of rhenium heptoxide with water. These compounds are the more important rhenium salts. Rhenium metal powder (99.99 per cent pure) is produced by the reduction of ammonium perrhenate with hydrogen. The metal powder is pressed and sintered into bars which are cold-rolled to from different shapes. The cost of producing rhenium metal and rhenium salts is high. Recent research has been directed towards the development of processes whereby molybdenum and rhenium can be recovered economically from molybdenite concentrates by hydrometallurgy.

Properties and uses

Rhenium has become an important industrial metal because of special or unique properties. The metal is highly refractory, having a melting point of 3 100°C, second to that of tungsten, and maintains strength and ductility at high temperatures even after heating above the crystallization temperature. Its density is 21, exceeded only by that of the platinum group metals. Pure rhenium can be cold-worked, but requires high-temperature recrystallization annealing to ensure maximum ductility. It is difficult to work at normal hot-working temperatures because it tends to become brittle. The metal can be welded by tungsten-arc, inert-gas techniques; the welds being ductile. Rhenium has good corrosion resistance to halogen acids. Alloyed with tungsten or molybdenum, rhenium improves the ductility and tensile strength of these metals. At room temperature, rhenium has a high-resistivity property which finds application in the rapid initial heating of filaments and heating elements. Stable oxide film on rhenium does not appreciably increase electrical resistance because the oxides are conductive. This property, plus good resistance to wear and arc corrosion, makes the metal ideally suited for electrical contacts.

The United States is the world's largest consumer of rhenium and rhenium salts and used an estimated 2 630.8 kg of the metal in 1976 compared with 2 721.6 kg in 1975. The major use of rhenium in 1976 continued to be in bimetallic platinum rhenium catalysts used in reforming units to produce a high-octane gasoline of low-lead and no-lead content. According to the U.S. Bureau of Mines, about 90 per cent of the rhenium consumed in the United States in 1976 was used in the fabrication of bimetallic catalysts for the petroleum refining industry. Rhenium powder is used to produce ductile, high-temperature, tungsten-based alloys which are used in the electronic field. Other applications of rhenium are high-temperature thermocouples, temperature controls, heating elements, electronic devices, flashbulb filaments, heat shields and in research and development work.

Outlook

The development of rhenium as an industrial metal has taken place recently and has not shown any clearly-defined growth pattern. The potential supply of the metal is limited to that available from the treatment of byproduct molybdenite concentrates obtained from low-grade porphyry copper ores. The recovery of rhenium from molybdenite concentrates is relatively low, about 60 per cent, and research into processes to improve recovery could add to the supply of the metal. The recovery of molybdenite from the processing of porphyry copper ores is generally low, varying from 20 to 80 per cent, and any success in research on methods to improve this recovery rate would increase the supply of available rhenium.

Some of the molybdic oxide producers do not recover the rhenium content of the molybdenite concentrates processed by them because of the costs involved in installing the required equipment. These molybdic oxide operations could be an added source of rhenium.

In the short term, the major demand for rhenium will be its application as a bimetallic platinum-rhenium catalyst in the petroleum-refining industry. Demand in this application has not been as large as expected because of a reduction in the rate of expansion of new refining capacity and the development of less expensive catalysts not requiring rhenium. Success in research projects on new uses for rhenium could increase its consumption. Low potential rhenium reserves could be an important factor in limiting the development of new industrial uses for the metal. Rhenium metal and salts now available to the market are greater than the demand and stocks are expected to continue to grow. In the United States, the U.S. Bureau of Mines estimated stocks in the hands of consumers and producers at the end of 1976 at 6 842.7 kg compared with 6 531.7 kg at the end of 1975.

Prices

United States

	Perrhenic Acid (Rhenium Content)	U.S. Producer Powder
	($ U.S. per pound of rhenium)	
January 1 — December 31, 1976	515 ($1 135 per kg)	540 ($1 180 per kg)

Source: *Metals Week*

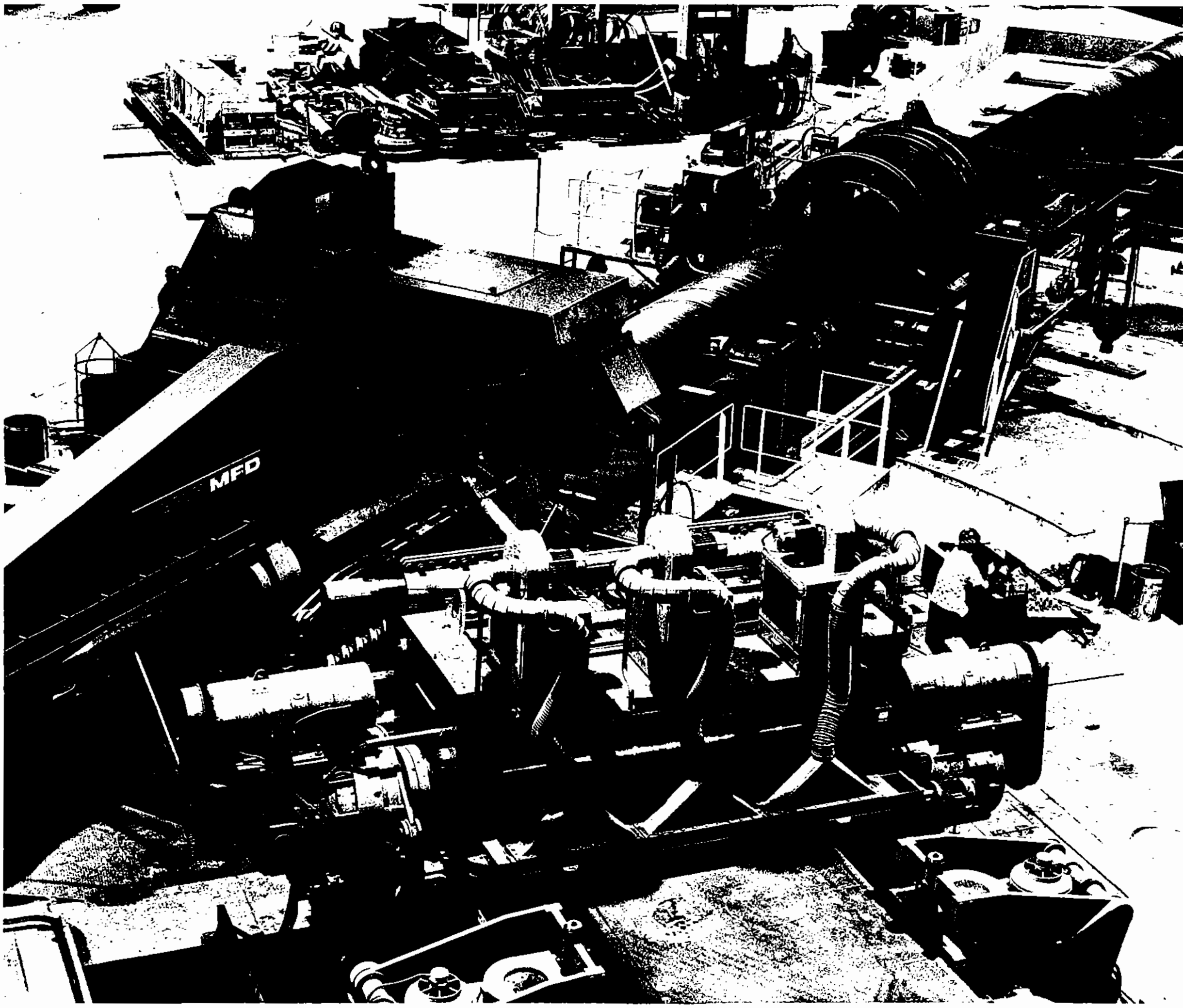
Tariffs

Canada — not specifically enumerated in Canadian tariffs

United States

Item No.		On and After January 1, 1976
		(%)
628.90	Rhenium unwrought, waste and scrap[1]	5
628.95	Rhenium wrought	9

Source: Tariff Schedules of the United States Annotated (1976) T.C. Publication 749.
[1]Duty on waste and scrap suspended until June 30, 1978.



Capable of turning out pipe for Canada's large-diameter pipelines, this spiral forming mill transforms steel plate into pipe at the Steel Company of Canada's Stelform plant at Welland, Ont.

Bogner photo — Welland

Salt

B.W. BOYD

In 1976 the Canadian salt industry recovered from the effects of the strikes which had reduced salt production in the previous year. Sales, at a record 5 855 251 tonnes*, were 14.3 per cent higher than in 1975 and 7.5 per cent greater than those of 1974. The value of exports increased by 84 per cent to $9 558 000. For the second consecutive year imports of salt exceeded exports.

Deposits and occurrences

Salt occurs in solution in seawater, in some spring and lake waters, in many subsurface waters, and in solid form in surface and underground deposits. Although seawaters contain the largest reserve of salt and contribute substantial quantities of solar evaporated salt to the world's annual output, underground bedded and dome deposits supply the largest part of the world's salt requirements.

In Canada, underground salt deposits have been found in all provinces except British Columbia. They have also been found in the District of Mackenzie, Northwest Territories, and in some of the Arctic islands. Bedded rock salt deposits in southwestern Ontario, Saskatchewan and Alberta, and dome deposits in Nova Scotia are the sources of most of Canada's salt output. In past years salt has been recovered from brine springs and natural subsurface brines in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta. Salt springs are also common to certain parts of British Columbia.

Production and developments in Canada

Canadian salt production falls into three categories: mined rock salt (3 mines); fine vacuum salt (6 evaporator plants); and salt in brine (4 brining plants) for chemical manufacture. One fine-salt plant used byproduct salt from a potash solution mine, and some byproduct salt from potash mines was processed for snow and ice control on roads.

In 1976, shipments of Canadian salt totalled 5 855 251 tonnes valued at $77 001 000. This is a 14.3 per cent increase in volume and a 28.9 per cent increase in value over the 1975 figures. Steady increases in the price of salt since 1970 have paralleled the inflation rate. Production of mined salt totalled 4 581 278 tonnes, about 36.5 per cent more than in 1975. Production of fine vacuum salt totalled 712 994 tonnes, about 27.6 per cent more than in 1975. The production of salt from brines increased by 4.9 per cent to 963 143 tonnes. For the third year in succession no salt was reported recovered in chemical operations.

Shipments of mined salt and fine vacuum salt were lower than production as producers' stockpiles were rebuilt after being drawn down during the strikes in 1975.

Atlantic region. Salt deposits occur in isolated subbasins of a large sedimentary basin that underlies the northern mainland of Nova Scotia and extends westward under the bordering areas of New Brunswick, northeastward under Cape Breton Island, Prince Edward Island, the Magdalen Islands and southwestern Newfoundland. The salt beds occur within the Mississippian Windsor Group and are generally folded and faulted. The deposits appear to be steeply dipping tabular bodies or domes and brecciated structures of rock salt.

The only salt production in the Atlantic provinces in 1976 was from a rock salt mine and associated evaporator plant at Pugwash, Nova Scotia and a brining operation near Amherst, Nova Scotia. In Richmond county and Inverness county, Domtar Limited and The Dow Chemical Company have explored salt domes for possible use as underground gas storage facilities.

The Canadian Rock Salt Company Limited reached agreement on a new contract with workers at the Pugwash, Nova Scotia mine, members of the Oil, Chemical and Atomic Workers Union. The contract language is set for two years but wages will be renegotiated after one year.

In New Brunswick two companies were active in potash and salt exploration during 1976. Potash Company of America, working on a lease granted in 1973,

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

drilled 20 holes before suspending drilling in August 1976 to begin development plans. In January the province issued a lease to International Minerals & Chemicals Corporation (Canada) Ltd. (IMCC) for the exploration and development of potash and salt on a 200-square-kilometre tract. To date IMCC has drilled ten holes in addition to the original hole put down as part of a program funded by the provincial and federal governments. In seven of the holes both potash and salt were intersected and the possibility of development of the two products is good.

Quebec. The Quebec government through Seleine Inc., a subsidiary of Quebec Mining Exploration Company (SOQUEM) advanced its plans to develop a salt mine on Grosse Ile in the Magdalen Islands. Total capital costs for the mine and an associated port are forecast to exceed $45 million. The viability of the project depends on Federal funding of the required port near the mine. SOQUEM expects initial production at the rate of about 900 000 tonnes a year to begin in 1980.

Table 1. Canada, salt production and trade, 1975-76

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Production	4 834 992	. .	6 257 415	. .
Shipments				
By type				
Mined rock salt	3 626 123	33 797 000	4 215 963	. .
Fine vacuum salt	578 650	22 324 000	676 145	. .
Salt content of brines used or shipped	917 800	3 593 000	963 143	. .
Total	5 122 573	59 714 000	5 855 2517	77 001 000^e
By province				
Ontario	3 762 965	32 259 074	4 323 501	45 081 000
Nova Scotia	767 932	14 509 494	902 492	17 642 000
Saskatchewan	276 403	7 509 598	278 525	7 764 000
Alberta	288 022	5 286 032	323 808	6 359 000
Manitoba	27 251	150 195	26 925	155 000
Total	5 122 573	59 714 393	5 855 251	77 001 000^e
Imports				
Salt and brine				
United States	934 725	8 932 000	1 160 692	10 581 000
Mexico	165 042	827 000	310 302	2 090 000
Bahamas	73 762	486 000	34 151	240 000
Spain	5 918	72 000	17 798	174 000
West Germany	100	23 000	182	15 000
Other countries	3 597	48 000	220	19 000
Total	1 183 144	10 388 000	1 523 345	13 119 000
Exports				
Salt and brine				
United States		5 123 000	1 421 674	9 479 000
St. Pierre-Miquelon		15 000	1 407	40 000
Poland		—	333	7 000
Jamaica		3 000	105	7 000
Leeward and Windward Islands		6 000	127	6 000
Bermuda		9 000	63	6 000
Other countries		22 000	138	13 000
Total	. .	5 183 000	1 423 847	9 558 000

Source: Statistics Canada.
^{p}Preliminary; . . Not available; — Nil; ^{e}Estimated.

Table 2. Canada, salt shipments, 1967-76

	Producers' Shipments					
	Mined Rock	Fine Vacuum	In Brine and recovered in Chemical Operations	Total	Imports	Exports
			(tonnes)			($)
1967	2 742 780	502 886	1 286 292	4 531 958	514 385	5 926 000
1968	2 930 483	501 927	980 430	4 412 840	584 366	5 921 000
1969	2 728 137	505 327	991 989	4 225 453	631 072	5 107 000
1970	3 272 520	552 704	1 036 285	4 861 509	560 659	7 430 000
1971	3 670 374	567 491	789 666	5 027 531	836 436	7 029 000
1972	3 539 017	579 256	795 879	4 914 152	929 189	4 988 000
1973	3 436 452	677 009	934 684	5 048 145	841 936	6 051 000
1974	3 783 078	692 109	971 533	5 446 720	736 573	6 851 000
1975	3 626 123	578 650	917 800	5 122 573	1 183 144	5 183 000
1976[p]	4 215 963	676 145	963 143	5 855 251	1 523 345	9 558 000

Source: Statistics Canada.
[p] Preliminary.

Ontario. Thick salt beds underlie much of southwestern Ontario, extending from Amherstburg northeastward to London and Kincardine, bordering on what is known geologically as the Michigan Basin. As many as six salt beds, occurring in the Upper Silurian Salina Formation and at depths from 275 to 825 metres, can be identified and traced from drilling records. Maximum bed thickness is 90 metres, with aggregate thickness reaching as much as 215 metres. The beds are relatively flat-lying and undisturbed, permitting easy mining.

In 1976 these beds were worked through two rock salt mines, one at Goderich and one at Ojibway, and through brining operations at Goderich, Sarnia, Windsor and Amherstburg. At the Ojibway mine, The Canadian Salt Company Limited completed a project designed to upgrade its underground haulage system.

Prairie Provinces. Salt beds underlie a broad belt of the Prairie Provinces extending from the extreme southwestern corner of Manitoba northwestward across Saskatchewan and into the north-central part of Alberta. Most of the salt deposits occur within the Prairie Evaporite Formation, which constitutes the upper part of the Middle Devonian, Elk Point Group, with thinner beds of salt occurring in Upper Devonian rocks. Depths range from 180 metres at Fort McMurray, Alberta, to 900 metres in eastern Alberta, central Saskatchewan and southwestern Manitoba, and to 1830 metres around Edmonton, Alberta, and in southern Saskatchewan. Cumulative thicknesses reach a maximum of 400 metres in east-central Alberta. The beds lie relatively flat and undisturbed. The same rock sequence contains a number of potash beds currently being exploited in Saskatchewan.

Salt was produced from these deposits at four locations in the Prairie Provinces in 1976: Saskatoon and Unity, Saskatchewan; and Lindergh and Fort Saskatchewan, Alberta. In addition, naturally occurring subsurface salt brines in Manitoba were used for caustic soda and chlorine manufacture at Brandon. Fine salt was also produced from byproduct brines from a potash solution mine at Belle Plaine, Saskatchewan. International Minerals & Chemical Corporation (Canada) Limited (IMCC) at Esterhazy, Saskatchewan, supplied a significant quantity of waste salt from potash mining for snow and ice control on highways.

Recovery method

Canadian producers employ three different techniques in the recovery of salt and/or brine from depth, the method employed depending upon the nature of the deposit and the type of salt in demand. Conventional underground mining methods are used to mine rock salt deposits that are relatively shallow and located in areas near large markets that do not specify a high-purity product.

Brining methods, too, are used to recover salt from subsurface deposits, usually from depths greater than mining depths. Brine can be evaporated to produce high-purity, fine, vacuum salt or it can be used directly in the manufacture of chemicals. Salt is similarly recovered from natural subsurface brines.

The third technique is to recover salt as a coproduct of potash mining, a practice quite common in Europe. In Canada the only commercial application of this technique is at a solution-type potash mine, where production methods permit the recovery of a good-quality salt brine. The other potash producers generally regard the waste salt as unmarketable, although some shipments have been made for use in snow and ice control.

A fourth method (not used in Canada) is solar evaporation of sea or salty lake waters, a process commonly used in warm, arid climates.

Rock salt mining

Access to rock salt deposits for conventional mining is through vertical shafts, normally 4.9 metres in diameter, serving the mining zone at depths of 192 to 536 metres. Mining is normally by the room-and-pillar method, the dimensions depending on the depth and thickness of the salt deposit. Rooms vary from 9 metres to 15 metres in width and from 5.5 to 15 metres in height, and pillars vary from about 18 to 61 metres square. Extraction ranges from 40 to 60 per cent. The mining operation consists of undercutting, drilling, blasting, loading and primary crushing. Underground haulage is generally by trucks and conveyor belts. Milling involves crushing, screening and sizing; at one mine the milling is done underground. The products, ranging in size from about one-half inch to a fine powder, normally have a purity of 96 per cent or better. Most of the gypsum, anhydrite and limestone impurities are removed during crushing and screening. Small amounts of the coarser salt fractions are further beneficiated by use of electronic sorters.

Most of the rock salt mined in Canada is shipped in bulk by water, rail and road, much of it being used for snow and ice control.

Brining and vacuum pan evaporation

Underground brining is accomplished by injecting water into a salt deposit to dissolve the salt, then pumping the resulting saturated salt solution to the surface. Water injection and brine recovery can be done through a single borehole with casing and tubing, or through a series of two or more cased wells. A brine field normally has from 2 to 20 wells, depending on the quantity of brine needed for the surface operation. Depths of the brine fields in Canada range from 335 to 1 980 metres. Saturated salt brine contains 26 per cent NaCl, which amounts to about three pounds of salt per gallon of fluid. At the surface the brine is either evaporated to produce fine vacuum salt, or used directly in the manufacture of chemicals.

Table 3. Canada, summary of salt producing and brining operations, 1976

Company	Location	Initial Production	Remarks
Nova Scotia			
The Canadian Salt Company Limited	Pugwash	1959	Rock salt mining at a depth of 630 feet.
	Pugwash	1962	Dissolving rock salt fines for vacuum pan evaporation.
Domtar Chemicals Limited	Amherst	1947	Brining for vacuum pan evaporation.
Ontario			
Allied Chemical Canada, Ltd.	Amherstberg	1919	Brining to produce soda ash.
The Canadian Salt Company Limited	Ojibway	1955	Rock salt mining at a depth of 980 feet.
The Canadian Salt Company Limited	Windsor	1892	Brining, vacuum pan evaporation and fusion.
Dow Chemical of Canada, Limited	Sarnia	1950	Brining to produce caustic soda and chlorine.

Table 3. (concl'd)

Company	Location	Initial Production	Remarks
Domtar Chemicals Limited	Goderich	1959	Rock salt mining at a depth of 1 760 feet.
	Goderich	1880	Brining for vacuum pan evaporation.
Prairie Provinces			
Hooker Chemical Canada Ltd.	Brandon, Man.	1968	Pumping natural brines to produce caustic soda and chlorine. Operation purchased from Dryden Chemicals Limited in 1974 (Dryden now under name of Reed Ltd.)
Northern Industrial Chemicals Ltd.[1]	Saskatoon, Sask.	1968	Brining to produce caustic soda and chlorine.
Domtar Chemicals Limited	Unity, Sask.	1949	Brining, vacuum pan evaporation and fusion.
The Canadian Salt Company Limited	Lindbergh, Alta.	1968	Brining, vacuum pan evaporation and fusion.
Dow Chemical of Canada, Limited	Fort Sasktachewan, Alta.	1968	Brining to produce caustic soda and chlorine.
The Canadian Salt Company Limited	Belle Plaine, Sask.	1969	Producing fine salt from byproduct brine from potash mine.
International Minerals & Chemical Corporation (Canada) Limited	Esterhazy, Sask.	1962	Byproduct salt from potash mine for use in snow and ice control.

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Managed by Canadian Industries Limited.

Canadian producers use a vacuum-pan process to evaporate the brine and produce fine salt. The brine is purified to remove gypsum and other impurities and fed into a series of three or four large cylindrical steel vessels under vacuum for triple or quadruple-effect evaporation. The salt crystallizes and is removed as a slurry, washed, filtered and dried. Product purity is generally 99.5 per cent or better.

Final processing involves screening, the introduction of additives, compression into blocks, briquettes or tablets; or compaction, recrushing and packaging to prepare as many as 100 different salt products. In some cases, quantities are melted at a temperature of about 815°C and allowed to cool. This produces a fused salt, which is particularly suitable for use in water softeners.

Canadian consumption and trade

Salt is marketed in at least 100 different forms, packages and containers and its direct and indirect uses number in the thousands. The largest single market for salt in Canada is for snow and ice control on highways and city streets. By comparison with other uses, this market is new, having expanded in Canada from less than 100 000 tonnes in 1954 to an estimated 2 224 234 tonnes in 1976.

The next-largest consumer of salt is the industrial chemical industry, particularly the manufacture of caustic soda (sodium hydroxide) and chlorine. Salt for four caustic soda and chlorine plants is obtained from on-site brining and natural brines; others use mined rock salt or imported solar salt. Other industrial chemicals that require significant quantities of salt in the manufacturing process include sodium carbonate (soda ash), sodium chlorate, sodium bicarbonate, sodium chlorite and sodium hypochlorite.

The pattern of Canada's salt trade has changed considerably in the past few years. Because of its low unit value and availability in most key market areas, salt is seldom hauled long distances, except in the case of seaborne and intercoastal shipments where greater mileage entails little additional cost.

Canadian exports of salt increased in 1976 to set a new record in value at $9 558 000 but the balance of trade in salt is still in the United States' favour.

Canadian imports of salt increased by 29 per cent in spite of the return of the domestic industry to normal production and shipment levels. Imports of salt to Canada in 1976 were from the United States (76 per cent) and Mexico (20 per cent).

Table 4. World salt production, 1974-76

	1974	1975[p]	1976[e]
	(000 tonnes)		
United States	42 243	37 222	38 135
People's Republic of China	25 000	29 937	30 844
U.S.S.R.	12 500	13 000	13 336
West Germany	11 320	8 452	8 618
United Kingdom	8 421	8 430	8 618
Mexico	5 470	6 350	6 532
India	5 916	6 350	6 441
Canada	5 464	4 835	6 257
France	6 272	5 537	5 625
Australia	4 935	4 990	5 080
Italy	4 894	4 412	4 536
Poland	3 295	3 514	3 629
Other countries	29 079	29 134	29 665
Total	164 809	162 163	167 316

Sources: U.S. Bureau of Mines, Mineral Trade Notes, January-February, 1977 and Commodity Data Summaries, January 1977; for Canada, Statistics Canada.
[p] Preliminary; [e] Estimated.

Table 5. Canada, available data on salt consumption, 1973-76

	1973	1974	1975[e]	1976[e]
	(tonnes)			
Snow and ice control[1]	2 016 255	2 218 661	2 301 541	2 224 234
Industrial chemicals	1 200 422	1 425 004	1 540 395	1 656 500
Fishing industry[e]	81 600	87 100	96 700	97 400
Food processing				
Fruit and vegetable preparation	20 172	19 832	31 406	21 200
Bakeries	14 181	17 536	15 012	16 900
Fish products	16 268	15 689	17 080	16 900
Dairy factories and process cheese	7 533	8 431	8 400	8 400
Miscellaneous food preparation	20 073	21 208	21 000	21 200
Grain mills[2]	55 932	55 329	58 900	59 300
Slaughtering and meat packing	37 115	34 338	46 300	46 600
Pulp and paper mills	58 051	31 639	50 500	50 800
Leather tanneries	8 479	10 734	9 074	8 500
Soap and cleaning compounds	4 693	2 527	4 200	4 200
Textile dyeing and finishing	1 448	1 442	1 300	1 300
Breweries	678	421	370	700

Sources: Statistics Canada; Salt Institute.
[1] Fiscal year ending June 30. [2] Includes feed and farm stock salt in block and loose forms.
[e] Estimated by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

Table 6. Canada, salt imports by province of landing, 1976

	Calendar Year 1976	
	(tonnes)	($)
Newfoundland	36 554	398 000
Nova Scotia	220	16 000
New Brunswick	157	20 000
Quebec	667 554	5 755 000
Ontario	331 514	2 743 000
Saskatchewan	286	28 000
Alberta	935	22 000
British Columbia	486 125	4 137 000
Total	1 523 345	13 119 000

Source: Statistics Canada.

World review

The Mexican government has increased its interest in Explotadora de Sal S.A. from 25 per cent to 51 per cent. The other owner is the Mitsubishi group of Japan. The Mexican move follows the price increase to $7 per short ton which in 1975 was enforced by the Mexican government and which restricted exports from Explotadora, one of the largest salt mining complexes in the world.

Early in 1976 Australia followed the lead set by Mexico in 1975 and forced renegotiation of salt prices, bringing them in line with the new Mexican price.

Outlook

The growth in imports during 1975 and 1976 cannot be fully explained by the fall in domestic production due to the strikes in 1975. The unfavorable balance of trade in salt may continue, therefore, as demand in British Columbia increases; that market being served by imports from the United States and Mexico.

The long-term outlook for the salt industry in Canada is continued stability and slow growth in response to growth in the road salt and chemical markets. Development of a new mine in eastern Canada will likely create a production surplus and may cause cutbacks at other salt operations in the area.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92501-1	Common salt (including rock salt)	free	free	5¢/100 lb.	free
92501-2	Salt for use of the sea or gulf fisheries	free	free	free	free
92501-3	Table salt made by the admixture of other ingredients when containing not less than 90 per cent of pure salt	5%	5%	15%	3%
92501-4	Salt liquors and sea water	free	free	free	free

United States

Item No.		
420.92	Salt in brine	5%
420.94	Salt in bulk	0.8¢ per 100 lb.
420.96	Salt, other	free

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa, Canada. For United States, Tariff Schedules of the United States annotated (1976) TC Publication 749.

Sand and Gravel

D.H. STONEHOUSE

Unconsolidated granular mineral material produced by the natural disintegration of rock under weathering and erosion processes is termed either "sand" or "gravel". The terms relate to grain size rather than to composition. Sand is defined very generally as passing a 9.51 mm sieve, almost all passing a No. 4 (4.76 mm) sieve, and almost all remaining on a No. 200 (74 micron) sieve. Gravel is that granular material remaining on a No. 4 sieve — the cut-off between commercial sand and gravel. Material finer than 200-mesh is referred to as silt or clay, depending on the particle size.

Commercial sand and gravel deposits are generally classified into one of four categories according to origin or method of deposition. Deposits composed of sand and gravel that had been carried by rivers and streams are referred to as fluvial deposits. They exhibit limited size gradation, and the distribution of size ranges and shapes can vary greatly, depending on whether the streams had been meandering, fast-flowing, narrow or shallow. Glacial deposits were distributed from massive ice sheets over large areas of Canada and the United States as well as other countries. They consist of rock particles of various types, shapes and sizes and display little sorting or gradation. Marine and lake deposits are usually of hard, tough material, well-segregated and well-worn to rounded shapes. Unstratified mixtures of sand and gravel, covering the complete size range and occurring on top of the parent rock, are termed residual deposits. These are not usually of commercial importance because of the large amount of softer clays associated with the mass.

The Canadian industry

Activity in the construction industry in Canada, particularly the heavy or engineering construction segment, determines to a great extent the amount of aggregate produced and used. The construction industry is often the first to be influenced by changes in the economic climate and, as suppliers of raw materials to such a volatile industry, the producers of sand and gravel and other aggregates must be capable of adjusting to periods of high and low activity thus created, as well as to surges in demand caused by regional and seasonal construction programs.

Sand and gravel deposits are widespread throughout Canada, and large producers have established "permanent" plants as close to major consuming centres as possible. Urban expansion has greatly increased demand for sand and gravel in support of major construction. Paradoxically, urban spread has not only tended to overrun operating pits and quarries, but has extended at times to areas containing mineral deposits, thereby precluding the use of these resources. Further complications have arisen in recent years as society has become increasingly aware of environmental problems and the need for planned land utilization. Municipal and regional zoning must be designed to determine and regulate the optimum utilization of land, but must not be designed to provide less than optimum resource utilization. Industry must locate its plants so as to minimize any adverse effects on the environment from their operations. Also, provision must be made for rehabilitation of pit and quarry sites in order to ensure the best sequential land use. The frequency with which small quarries and pits materialize to supply short-lived, local demands, leaving unsightly properties, has prompted action by municipal and provincial governments to control or to prohibit such activity.

Ideally, the exploitation of sand, gravel and stone deposits should be done as part of the total land use planning package, such that excavations are designed to conform with a master plan of development and even to create new land forms. Ontario seems to be leading other provinces in enacting legislation to control pit and quarry licensing, operation and rehabilitation, and its new laws are typical of what can be expected in other provinces. The urgency associated with the aggregate situation in Ontario, being greater than in other provinces, was a major reason for the formation of a Mineral Aggregate Working Party by the Ontario Government in December, 1975. The Working Party brought together representatives of the Ministry of Natural Resources, the Ministry of Housing, the

Ministry of the Environment, the Ministry of Treasury, Economics and Intergovernmental Affairs, the Ministry of Transport and Communications, municipal governments, the Niagara Escarpment Commission and the Conservation Council of Ontario; and through a series of public meetings entertained proposals from all interested persons relative to all aspects of aggregate identification, production and utilization. The working party's report contains a number of recommendations which should lead to the development of a policy for mineral aggregate resource management in Ontario. Ontario's current regulations apply to operations in designated areas of the province and to rehabilitation of depleted sites.

Inventories indicating the potential available reserves of sand, gravel and stone should be prerequisite to legislation regulating land use. Surveys to locate such resources are being carried out in many provinces in order to optimize their use and to choose the best possible distribution routes to consuming centres. It should be observed that controls and zoning can reduce reserves of these resources significantly.

In addition to large aggregate operations usually associated with some other phase of the construction industry such as a ready-mix plant or an asphalt plant, there are many smaller, privately owned producers serving small, localized markets. These are often operated on a seasonal or part-time basis. Many larger operations are short-term, intermittently serving as a supply arm of a heavy construction company, and providing material for a given project. Provincial departments of highways operate regional or divisional quarries to supply roadbed material for new and repair work. Exploitation by such a large number of widely diversified groups not only makes control difficult, it also provides great obstacles to the collection of accurate total production data.

Although producers' shipments, as recorded by Statistics Canada (Catalogue 26-215), reflect the total amounts of sand and gravel recovered by all producers regardless of statistical classification, only about 150 "establishments" are listed, showing a total employment of less than 2 000 persons. More detailed data from individual provincial government departments such as highways, municipal affairs, natural resources, lands and forests are required to reveal the total number of active pit and quarry operations.

Materials competitive with sand and gravel include crushed stone and the lightweight aggregates, depending on the application considered. It has been estimated that total aggregate consumption in some Canadian urban centres could reach 18 tonnes* per capita by

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, construction spending by provinces, 1975-77

	1975[1]	1976[2]	1977[3]
	(millions of dollars)		
Newfoundland	617.1	712.5	750.2
Prince Edward Island	107.5	95.3	95.9
Nova Scotia	764.2	852.1	949.2
New Brunswick	829.0	785.7	812.2
Quebec	7 111.0	7 469.5	8 188.6
Ontario	8 989.4	9 831.2	10 155.4
Manitoba	1 012.6	1 232.5	1 311.6
Saskatchewan	1 130.5	1 381.4	1 533.2
Alberta	3 920.9	5 052.9	5 756.9
British Columbia, Yukon and Northwest Territories	3 894.1	4 360.1	4 796.1
Canada	28 376.3	31 773.2	34 349.3

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

Table 2. Canada, production (shipments) sand and gravel by provinces, 1974-76

	1974		1975		1976[p]	
	(000 tonnes)	($000)	(000 tonnes)	($000)	(000 tonnes)	($000)
Newfoundland	6 144	8 728	6 237	9 587	5 080	9 200
Prince Edward Island	884	1 454	929	1 787	816	1 700
Nova Scotia	10 504	16 169	8 906	14 043	8 618	14 400
New Brunswick	7 485	5 558	3 834	4 239	3 538	4 100
Quebec	60 248	48 223	82 039	70 488	83 007	75 900
Ontario	72 561	85 518	69 705	95 579	68 039	95 200
Manitoba	17 271	22 168	16 417	22 934	17 418	25 200
Saskatchewan	10 741	9 736	8 313	10 672	7 439	10 200
Alberta	22 410	31 166	20 453	33 952	23 133	42 100
British Columbia	31 048	35 265	30 322	41 900	30 572	42 800
Canada	239 296	263 985	247 155	305 181	247 660	320 800

Source: Statistics Canada.
[p]Preliminary.

Table 3. Production (shipments) sand and gravel, by uses, by areas, 1974-75

		Atlantic Provinces	Quebec	Ontario	Western Provinces	Canada
				(000 tonnes)		
Roads	1974	19 988	42 869	38 517	38 930	140 304
	1975	15 493	52 868	35 633	39 898	143 892
Concrete aggregate	1974	1 698	5 542	16 541	15 003	38 784
	1975	1 623	10 520	14 491	12 486	39 120
Asphalt aggregate	1974	2 118	2 114	4 026	6 385	14 643
	1975	1 892	5 934	4 717	6 025	18 568
Railroad ballast	1974	187	287	252	3 648	4 374
	1975	179	521	202	3 224	4 126
Mortar sand	1974	59	76	2 461	751	3 347
	1975	53	438	2 037	604	3 132
Backfill for mines	1974	125	115	887	3	1 130
	1975	112	226	1 508	137	1 983
Other fill	1974	828	9 066	9 458	14 821	34 173
	1975	544	6 584	9 963	11 440	28 531
Other uses	1974	12	179	419	1 931	2 541
	1975	9	4 948	1 154	1 692	7 803
Total sand and gravel	1974	25 015	60 248	72 561	81 472	239 296
	1975	19 905	82 039	69 705	75 506	247 155

Source: Statistics Canada, with breakdown by Statistics Section, Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

Table 4. Canada, exports and imports of sand and gravel, 1974-76

	1974		1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
Exports						
Sand and gravel						
United States	356 633	775 000	138 399	352 000	377 599	551 000
Spain	—	—	—	—	36	5 000
France	—	—	9	1 000	18	2 000
Other countries	457	5 000	44	12 000	—	—
Total	357 090	780 000	138 452	365 000	377 653	558 000
Imports						
Sand and gravel, not elsewhere stated						
United States	1 572 595	2 465 000	1 909 319	3 530 000	2 068 583	3 790 000
West Germany	309	20 000	575	10 000	1 959	5 000
Hong Kong	—	—	—	—	26	. . .
Total	1 572 904	2 485 000	1 909 894	3 540 000	2 070 568	3 795 000

Source: Statistics Canada.
— Nil; . . . Less than one thousand dollars; [p]Preliminary.

1980. Estimates have indicated that available sand and gravel supplies in some regions will be depleted by the 1990s. This could make outlying deposits not only attractive but necessary, and could also encourage development of underwater deposits. Marine aggregates now account for about 12 per cent of total sand and gravel production in the United Kingdom, the world's largest producer from such resources. It is not completely impossible that areas of concentrated population, such as the eastern seaboard of the United States where reserves of aggregate are already becoming depleted, will have to import their requirements, perhaps from offshore by boat or barge. Large tonnages of crushed limestone are exported annually from Canada's west coast quarries, particularly from Texada and Aristazabal islands, for cement, lime and aggregate use in Oregon and Washington.

The main uses for sand and gravel are: as fill, granular base-and finish-course material for highway construction, coarse and fine aggregates in concrete manufacture, coarse aggregate in asphalt production, and fine aggregate in mortar and concrete blocks. Specifications vary greatly, depending on the intended use, and many tests are required to determine the acceptability of aggregates for certain applications. Particle size distribution of aggregates, as assessed by grading tests or sieve analysis, affects the uniformity and workability of a concrete mix as well as the strength of the concrete, the density and strength of an asphalt mix, and the durability, strength and stability of the compacted mass when aggregates are used as fill or base-course material. Of importance also are tests to determine the presence of organic impurities or other deleterious material, the resistance of the aggregate to abrasion and to freeze-thaw cycles, the effects of thermal expansion, absorption, porosity, reactivity with associated materials and surface texture.

The use of sand and gravel as backfill in mines continues, along with increasing use of cement and mill tailings for this purpose. Abrasive sands, glass sand, foundry sands and filter sands are also produced.

Even the common products such as sand and gravel require a sales and distribution effort which depends upon forecast data supplied by monitoring relevant indicators. One such indicator is the number of regional housing starts which, in turn, can be projected to determine future needs for roads, driveways, shopping centres and schools. Heavy construction awards can be used to provide an estimate of the quantity of aggregate required for given projects over given periods of time.

There is no standard price for sand and gravel. Prices are determined regionally, or even locally, by production and transportation costs, by the degree of processing required for a given end use and by the quantity of material required for a particular project. Increased land values, reduction of reserves and added rehabilitation expenditures should result in higher prices.

Table 5. Canada, production (shipments) sand and gravel, by uses, 1974-75

	1974	1975
	(000 tonnes)	
Roads — construction, maintenance, ice control	140 304	143 892
Concrete aggregate	38 784	39 120
Asphalt aggregate	14 643	18 568
Railroad ballast	4 374	4 126
Mortar sand	3 347	3 132
Backfill for mines	1 130	1 983
Other fill	34 173	28 531
Other uses	2 541	7 803
Total sand and gravel	239 296	247 155
$000	263 985	305 181

Source: Statistics Canada with breakdown by Statistics Section, Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

Sand and gravel must be quarried, screened, washed, stockpiled and transported in large volume to compensate for the relatively low unit value received. Transportation and handling often double the plant cost, making it necessary to utilize close-in reserves and influencing the scope of exploration for new deposits. The need for an inventory of aggregate materials surrounding regions of large population growth cannot be emphasized too strongly.

Unit trains, or more precisely, "hook and haul" trains, have been used to transport aggregate into the Toronto area in minimum loads of 4 000 tonnes at negotiated freight rates. The wide physical distribution of consumers within the area being served causes difficulties with such a system, as further handling and transporting is required.

Table 6. Canada, sand and gravel production (shipments) and trade, 1965, 1970, 1974-76

	Production	Imports	Exports
	(tonnes)		
1965	186 208 979	517 982	624 090
1970	183 846 431	456 077	1 125 083
1974	239 295 942	1 572 904	357 090
1975	247 155 421	1 909 894	138 452
1976^p	247 660 000	2 070 568	377 653

Source: Statistics Canada.
^{p} Preliminary.

Outlook

On average, total aggregate consumption will rise in line with population increases, housing requirements and construction in general. Sand and gravel consumption will continue in competition with crushed stone and, in some applications, with lightweight aggregates. New reserves must be located, assessed and made part of any community development planning or regional zoning, with optimum land and resource utilization in mind. In the search for new sources of sand and gravel some countries are turning to their sea beds. The use of huge pumps and specially equipped ships to draw gravel from the sea floor and deposit it in attendant barges is already common practice in Britain. Such methods of obtaining aggregates can have far-reaching environmental effects.

Prices for graded, washed and crushed gravel and sand will show slow but steady increase, based on greater property costs, more sophisticated operating techniques and equipment, pollution and environmental considerations, and higher labour and transportation costs.

Table 1. Canada, selenium production, exports and consumption, 1975-76

	1975		1976p	
	(kilograms)	($)	(kilograms)	($)
Production				
All forms[1]				
Quebec	124 603	5 029 794	159 000	6 986 000
Ontario	48 852	1 971 987	49 000	1 951 000
Manitoba	6 449	260 332	34 000	1 296 000
Saskatchewan	2 481	100 156	18 000	675 000
Total	182 385	7 362 269	260 000	10 908 000
Refined[2]	342 391	..	226 622	..
Exports (metal)				
United States	130 181	7 110 000	139 479	6 701 000
United Kingdom	85 048	3 440 000	87 044	3 441 000
Japan	453	23 000	10 477	560 000
Argentina	136	10 000	1 270	58 000
Puerto Rico	226	5 000	861	40 000
South Africa	—	—	997	39 000
Colombia	498	31 000	635	26 000
Other countries	1 454	173 000	185	5 000
Total	217 996	10 792 000	240 948	10 870 000
Consumption[3] (selenium content)	9 933	..	11 212	..

Source: Statistics Canada.
[1]Recoverable selenium content of blister copper treated at domestic refineries, plus refined selenium from domestic primary materials. [2]Refinery output from all sources, including imported materials and secondary sources. [3]Available data, consumption of selenium products; selenium content, as reported by consumers.
pPreliminary; .. Not available; — Nil.

United States in 1976 was estimated by the United States Bureau of Mines (USBM) to have been; electronic components, 35 per cent: ceramics and glass, 30 per cent; chemicals and pigments, 25 per cent and other uses, 10 per cent.

An important, but declining, use of selenium is in the electrical products field, where it finds application in the manufacturing of rectifiers used in electroplating, welding, battery charging and other similar applications. Selenium is used in specialty transformers varying in size from a fraction of a watt to 500 kilowatts. Xerography (electrostatic printing), a dry photocopying or photographing process, uses a large quantity of selenium. In semi-conductors, selenium has largely been replaced by silicon.

The glassmaking industry is one of the major consumers of selenium. Small quantities added to the glass batch neutralize the greenish tinge imparted to glass by iron impurities in the sand. Selenium is meeting with some competition from cerium in this application. The brilliant ruby-red glass used in traffic and other signal lenses, automotive taillights, marine equipment, infrared equipment and decorative tableware is produced by adding larger quantities of selenium to the glass batch. An increasing amount of selenium is used in tinted "black" glass which is used as the outer facing of many highrise office buildings.

Selenium has wide application in the chemical industry, the most important being the manufacture of the orange-red-maroon cadmium sulphoselenide pigments. They have considerable light stability, maintain their brilliance and are resistant to heat and chemical action. Their most important application is in the expanding high-temperature, cured-plastic industry, but they are also used to colour ceramics, paints, enamels and inks.

In amounts ranging from 0.2 to 0.35 per cent, selenium imparts improved machinability to stainless steel without affecting its corrosion-resistance properties, and in lesser amounts improves the forging characteristics of steel. Small quantities of iron selenide, from 0.01 to 0.05 per cent, are used as an additive in steel casting to prevent pinhole porosity.

Finely ground selenium and selenium diethyldithio-carbamate (selenac) are used in natural and synthetic rubber to increase the rate of vulcaniza-

Table 2. Canada, selenium production, exports and consumption, 1965, 1970, 1974-76^p

	Production			
	All Forms[1]	Refined[2]	Exports Metals[3]	Consumption[4]
	(Kilograms)			
1965	232 274	233 416	204 660	7 206
1970	300 884	387 572	311 209	7 135
1974	272 132	333 949	420 706	13 825
1975	182 385	342 391	217 996	9 933
1976^p	260 000	226 622	240 948	11 212

Source: Statistics Canada.
[1]Recoverable selenium content of blister copper treated at domestic refineries, plus refined selenium from domestic primary material. [2]Refinery output from all sources, including imported material and secondary sources. [3]Exports of selenium, selenium powder, shot, etc. [4]Consumption (selenium content), as reported by consumers.
^p Preliminary.

Table 3. Noncommunist world production of selenium, 1974-76^e

	1974	1975	1976^e
	(Kilograms)		
Japan	362 873	416 851	430 912
Canada	272 132	182 385	260 000
United States	292 113	162 386	184 158
Mexico	49 895	58 059	58 967
Belgium and Luxembourg	55 791	47 627	45 359
Other countries	169 189	148 776	102 054
Total	1 201 993	1 016 084	1 081 450

Sources: For Canada, Statistics Canada. U.S. Bureau of Mines Commodity Data Summaries, January 1976 and 1977.
^e Estimated.

tion and to improve the aging and mechanical properties of sulphurless and low-sulphur rubber. Selenac is used as an accelerator in butyl rubber.

Selenium is used in the organic chemical and pharmaceutical industries, in the manufacture of cortisone and nicotine acids, in the preparation of various proprietary medicines and shampoos for the control of dermatitis in human beings and animals, and in the control of certain diseases in animals and poultry. It is known that selenium is an essential element for normal physical development and prevents white muscle disease in livestock and poultry. Growing attention within this field could result in a large new market for selenium as a feed supplement. In the United States, the Food and Drug Administration has proposed that selenium be added to poultry and swine feed. However, selenium is highly toxic to both livestock and human beings if consumed in excessive quantities.

Table 4. Canada, industrial use of selenium, 1973-75

	1974	1975	1976^p
	(kilograms of contained selenium)		
By end use			
Glass	10 088	7 420	8 448
Other[1]	3 737	2 514	2 764
Total	13 825	9 934	11 212

Source: Statistics Canada.
[1]Steel, pharmaceuticals.
^p Preliminary.

A small amount of selenium is used in the manufacture of delay-action blasting caps.

Interest has been revived in the use of selenium in the photogalvanic cell, which converts light energy to electrical energy, as new sources of energy are sought to offset fuel and energy shortages. Also, with respect to the energy situation, an increased demand for selenium-tinted windows, which have a lower heat conductivity than conventional glass is expected.

Outlook

Selenium production is primarily a byproduct of copper refining, but the relationship is trending towards a lower quantity of selenium output as existing selenium-rich copper reserves are exhausted. An increasing amount of copper production is being derived from selenium-poor ores. Furthermore, environmental standards are leading to technical changes in copper extraction processes that may result in lower selenium recoveries unless a new technology is developed to extract it.

It is likely that Canadian production of selenium will gradually decline in the medium-term for the reasons mentioned above, but production in 1977 should be somewhat higher than in 1976 due to higher copper production. The expected growth in demand for selenium will probably result in a trend towards higher prices in the medium- to long-term.

Prices

Producer prices for commercial grade and high-purity grade selenium in the United States remained unchanged throughout 1976 at $U.S. 18 and $U.S. 21 to 22 a pound, respectively. Dealer prices in the United States rose during the first four months to a peak of $20 a pound late in April. At the end of 1976 dealer prices declined to $U.S. 12.75 to 13.75 a pound.

According to "Metals Week", United States selenium prices per pound for 1976 were:

	Commercial Grade	High-Purity Grade
January 1 to December 31	$18.00	$21.00–22.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferences
92804-4	Selenium metal	5%	10%	15%	5%

United States

Item No.		
420.50	Selenium dioxide	free
420.52	Selenium salts	free
420.54	Other selenium compounds	5%
632.40	Selenium metal, unwrought, other than alloys, waste and scrap	free
632.84	Selenium metal alloys, unwrought	9%
633.00	Selenium metals, wrought	9%

European Communities

Item No.		Conventional Rate
28.04 C.11	Selenium metal	free

Japan

Item No.		GATT Rate
28.04.30	Selenium metal	10% (temporarily reduced to 8%)

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. Tariff Schedules of the United States Annotated 1976, T.C. Publication 749. Official Journal of the European Communities, 15 November 1976, Customs Tariff Schedules of Japan, 1976.

TELLURIUM

Like selenium, tellurium is recovered in Canada from the tankhouse slimes of the two electrolytic copper refineries and the Port Colborne nickel refinery. It is refined by the same two companies: Canadian Copper Refiners Limited at Montreal East, Quebec, and Inco Limited at Copper Cliff, Ontario.

Production of tellurium in all forms from Canadian ores in 1976 amounted to 24 000 kilograms valued at $529,000, compared with 19 854 kilograms valued at $414,074 in 1975. Tellurium is related to selenium output because tellurium is a coproduct of selenium recovery. Refined output from all sources, including imported material, for the years 1976 and 1975 was 53 141 kilograms and 42 252 kilograms, respectively.

Canadian Copper Refiners Limited (CCR) has an annual capacity to produce 27 200 kilograms of tellurium in the form of powder, stick, lump and dioxide. The Copper Cliff refinery has capacity to produce 8 200 kilograms of tellurium a year in the form of dioxide.

The byproduct plant at the CCR copper refinery experienced a period of reduced production in 1976.

Table 5. Canada, tellurium production and consumption, 1975-76

	1975		1976p	
	(kilograms)	($)	(kilograms)	($)
Production				
All forms[1]				
Quebec	10 200	212 746	15 000	331 000
Ontario	6 934	144 606	6 000	138 000
Manitoba	1 965	40 971	2 000	40 000
Saskatchewan	755	15 751	1 000	20 000
Total	19 854	414 074	24 000	529 000
Refined[2]	42 252	..	53 141	..
Consumption[3] (refined)	614	..	589	..

Source: Statistics Canada.
[1]Recoverable tellurium content of blister copper treated, plus refined tellurium from domestic primary material; [2]Refinery output from all sources, including imported material and secondary sources; [3]Available data, reported by consumers.
p Preliminary; .. Not available.

This was due to the installation and tune-up of new environmental equipment at the plant. Tellurium and selenium production were both affected.

Consumption and uses

Tellurium is recovered mainly as a byproduct of copper refining and the supply is, therefore, related to copper production. Under present technological practices a low ratio of recovery is obtained, but it is adequate to meet demand. Tellurium and many of its compounds are highly toxic, and great care is required in handling these materials.

Most of the commercial-grade tellurium sold by the primary producers is in the form of slab, stick, lump, tablet and powder. It is also sold as copper and iron alloys.

In the United States, consumption by major uses in 1975 was estimated to be: iron and steel 70 per cent, nonferrous metal products 19 per cent, chemicals 6 per cent and other, 5 per cent.

The primary metal industries are by far the largest consumers of tellurium. Added to copper, and low carbon and alloy steels, the machinability of these metals is greatly improved. In stainless steel castings it reduces or prevents pinhole porosity. A very small quantity of tellurium added to molten iron controls the chill depth of grey-iron castings. An alloy containing 99.5 per cent copper and 0.5 per cent tellurium is used in the manufacture of welding tips and communications equipment because it can be hot- or cold-worked, and the thermal and electrical conductivity is only slightly less than that of copper. Up to 0.1 per cent tellurium in lead forms an alloy that has better resistance to wear, vibration breakdown and corrosion, and, because of these properties, is used to sheathe marine cables and to line tanks subject to chemical corrosion.

Tellurium, as a component of alloys containing gallium, bismuth and lead, is used in thermoelectric devices for the direct conversion of heat into electricity, and for cooling as a result of its Peltier effect. A thermonuclear heart pacemaker that employs the thermoelectric principle is under development. In the device, nuclear power provides heat and a tellurium alloy converts the heat to electrical energy. The minimum life of this experimental pacemaker is reported to be ten years.

Table 6. Canada, production and consumption of tellurium, 1965, 1970 and 1974-76

	Production		Consumption
	All Forms[1]	Refined[2]	Refined[3]
	(kilograms)		
1965	31 658	32 536	848
1970	26 459	29 317	390
1974	56 387	62 609	444
1975	19 854	42 252	614
1976p	24 000	53 141	589

Source: Statistics Canada.
[1]Includes recoverable tellurium content of blister copper, not necessarily recovered in year designated, plus refined tellurium from domestic primary metal. [2]Refinery production from all sources, including imported material and secondary sources. [3]Available data, reported by consumers.
p Preliminary.

Tellurium is used as a secondary vulcanizing agent in natural and synthetic rubber in which it increases toughness and resistance to abrasion and heat. These characteristics make possible its application for the jacketing of portable electric cable used in mining, dredging, and welding, and for specialized conveyor belting. Tellurium is employed to eliminate porosity in thick rubber sections and as an accelerator for butyl applications.

Some tellurium is consumed in glass and ceramic production to develop blue-to-brown coloration, in the preparation of insecticides and germicides, and in the manufacture of delay-electric blasting caps and pigments.

Table 7. Noncommunist world production of tellurium, 1974-76

	1974	1975	1976[e]
	(kilograms)		
United States	86 636	59 420	..
Canada	56 387	19 854	24 000
Peru	27 215	31 751	31 751
Japan	25 854	21 318	22 679
Total	196 092	132 343	..

Sources: For Canada, Statistics Canada. For other countries, U.S. Bureau of Mines Commodity Data Summaries, January 1976 and 1977.
[e] Estimated; .. Not available.

Outlook

Supply is largely limited to that which is available from copper output and, as in the case of selenium, new copper production is increasingly derived from tellurium-poor ores. In the short-to-medium term a slow growth in demand is expected, in the range of zero to 2 per cent, and supply will be adequate to meet requirements. Substitutes are readily available for the major uses and will tend to constrain an increase in consumption and to hold price changes to modest increases.

Prices

According to *Metals Week*, the United States tellurium price per pound for slab in 150-pound lots was as follows:

January 1 to June 30	$10.00
July 1 to October 31	$10.00 – $12.00
November 1 to December 31	$12.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferences
92804-5	Tellurium metal	5%	10%	15%	5%

United States

Item No.		
421.90	Tellurium compounds	5%
427.12	Tellurium salts	5%
632.48	Tellurium metal, unwrought, other than alloys, and waste and scrap (duty on waste and scrap suspended to June 30, 1978)	4%
632.84	Tellurium metal alloys, unwrought	9%
633.00	Tellurium metal, wrought	9%

European Communities

Item No.		Conventional Rate
28.04 C.111	Tellurium metal	2.4%

Japan

Item No.		GATT Rate
28.04.30	Tellurium metal	10% (temporarily reduced to 8%)

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division. Tariff Schedule of the United States Annotated, 1976, T.C. Publication 749. Official Journal of the European Communities; 15 November 1976. Customs Tariff Schedules of Japan, 1976.

Silica

G.H.K. PEARSE

Silica (SiO_2) occurs as the mineral, quartz, in a variety of rocks and unconsolidated sediments. Although it is one of the most abundant minerals, making up an estimated 12 per cent of the earth's crust, commercial sources of silica are presently restricted to uncommonly pure sands, sandstones, quartzites and vein quartz. Further, because of its low unit value, an economically viable deposit should normally be mineable by low-cost, open-pit methods and, ideally, be located close to consuming areas in order to minimize transportation costs.

The principal uses for silica are: as the chief constituent in glass, as metallurgical flux, in the manufacture of silicon carbide, as an ore of silicon and ferrosilicon, as foundry sand for metal castings, in sand blasting, and as filler materials in tile, asbestos cement pipe, concrete and bricks.

Production of silica in Canada in 1976 was 2.38 million tonnes*, down 4 per cent from 1975. The record 2.94 million tonnes shipped in 1970 remains unsurpassed.

About 60 per cent of silica produced in Canada is low-value lump and sand consumed as metallurgical flux. High-quality silica sand suitable for the manufacture of glass is produced by two companies in Canada. Indusmin Limited, the largest, operates beneficiation plants in southern Ontario and Quebec. Steel Brothers Canada Ltd. quarries high-grade silica sandstone on Black Island in Lake Winnipeg and processes the material at the company's plant at Selkirk, Manitoba.

Canada imports high-grade silica sand for use in glass manufacturing, sand suitable for foundry castings, silex and crystallized quartz and silica brick. In 1976, imports, nearly all from the United States, totalled a record 1.35 million tonnes, 27 per cent more than in 1975.

Principal producers and developments

Newfoundland. Newfoundland Enterprises Limited, a subsidiary of Armand Sicotte & Sons Limited, produces silica from a quarry at Villa Marie on the Avalon Peninsula. The silica is hauled by truck 19 kilometres to Long Harbour where it is used as a flux in the manufacture of elemental phosphorus by Erco Industries Limited. This plant requires about 100 000 tons of silica annually.

Quebec. Indusmin Limited produces a wide variety of silica products at its mill near Saint-Canut, Quebec. In addition to quarrying Potsdam sandstone adjacent to the Saint-Canut mill, the company quarries a friable Precambrian quartzite from a deposit near Saint-Donat. Material from the Saint-Donat quarry is trucked about 80 kilometres to the Saint-Canut mill for processing. Products produced at Saint-Canut include silica sand suitable for glass and silicon carbide manufacture, foundry sand, and silica flour for use as a filler in tiles, asbestos cement pipe, concrete blocks and bricks. Production at Indusmin's operation in Quebec was 382 000 tonnes in 1976, up 5 per cent from 1975 despite severe operating conditions during part of the winter. Ore reserves at the two deposits are reported to be 12 430 000 tonnes combined. The silica sand suitable for glass manufacture is marketed in Quebec, while much of the product suitable for use in the construction industry is sold in Ontario. The balance of Quebec's silica sand requirements for glass manufacture is imported from the United States.

Union Carbide Canada Mining Ltd. quarries quartzitic sandstone at Melochville, Beauharnois County, for use in ferrosilicon manufacture at Beauharnois. Fines from this operation are used in foundry work, cement manufacture and as a metallurgical flux. Silice L.M. Ltée at Lac Bouchette, Roberval produces about 15 000 tonnes from vein quartz for Union Carbide's silicon plant at Chicoutimi.

During 1975, Baskatong Quartz Products Ltd. closed its plant which had produced lump silica and crushed quartz from a deposit on the southwest shore of Lake Baskatong. The lump silica was used in the manufacture of silicon metal and to a lesser extent as

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, silica production and trade, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production, quartz and silica sand[1]				
By province				
Ontario	1 096 237	4 358 086	1 555 000	5 400 000
Quebec	548 355	5 334 201	523 000	5 075 000
Manitoba	618 040	1 865 039	442 000	1 517 000
Alberta	. .	839 928	. .	1 125 000
Nova Scotia	. .	130 090	. .	231 000
Newfoundland	. .	160 000	. .	218 000
Saskatchewan	109 478	168 951	102 000	168 000
British Columbia	18 097	255 835	31 000	161 000
Total	2 491 715	13 112 130	2 376 000	13 895 000
By use				
Glass and fiberglass	395 115	4 803 652	. .	. .
Flux	1 496 195	2 668 572	. .	. .
Ferrosilicon	203 858	982 929	. .	. .
Other uses[2]	396 547	4 656 977	. .	. .
Total	2 491 715	13 112 130	. .	. .
Imports				
Silica sand				
United States	1 044 104	9 163 000	1 339 724	9 721 000
Belgium and Luxembourg	—	—	2 734	13 000
United Kingdom	56	6 000	—	—
Total	1 044 160	9 169 000	1 342 458	9 734 000
Silex and crystallized quartz				
United States	1 545	302 000	862	220 000
United Kingdom	3	. . .	1	2 000
Brazil	2	3 000	—	—
Total	1 550	305 000	863	222 000
Firebrick and similar shapes, silica				
West Germany	774	284 000	5 087	1 776 000
United States	7 728	2 382 000	5 454	1 757 000
United Kingdom	3 097	1 102 000	218	120 000
Japan	5 472	3 535 000	78	12 000
France	—	—	13	6 000
Total	17 071	7 303 000	10 850	3 671 000
Exports				
Quartzite				
United States	39 977	225 000	47 943	249 000
Total	39 977	225 000	47 943	249 000

Source: Statistics Canada.
[1]Producers' shipments include crude and crushed quartz, crushed sandstone and quartzite and natural silica sand. [2]Includes foundry use, sand blasting, silica brick, concrete products, chemical manufacture, building products and silicon carbide.
pPreliminary; — Nil; . . Not available; . . . Less than $1 000.

grinding pebble. The crushed quartz was sold for use as exposed aggregate in decorative concrete. A new 52 000-tonne-a-year ferrosilicon plant came on stream at Bécancour, Quebec in 1976. The company, S.K.W. Electro-Metallurgy Canada Ltd., obtains its raw material from a high-purity silica deposit 40 kilometres north of Baie St. Paul near La Galette in Charlevoix County, operated by Baskatong Quartz Products. The silica is shipped by truck via Baie St. Paul to Bécancour. Silica production commenced in the fall of 1975 and totalled 12 000 tonnes by year-end. Output in 1976 was an estimated 20 000 tonnes.

Armand Sicotte & Sons Limited produces about 80 000 tonnes of silica for flux in phosphorus making at Erco Industries Limited's plant at Varennes.

Ontario. Indusmin Limited quarries a high-grade silica deposit on Badgeley Island in Georgian Bay. The deposit consists of very pure Precambrian Lorraine quartzite. A primary crushing plant at the deposit, some 190 kilometres north of Midland, across Georgian Bay, and a grinding and processing plant at Midland came on stream during the first half of 1970. The Badgeley Island operation has a capacity of approximately 1 million-tonnes-a-year of washed lump silica and fine material. The Midland plant capacity is about 500 000 tonnes a year of refined silica products. Primary products from the crushing plant on Badgeley Island are shipped directly to manufacturers of ferrosilicon and silicon metal, and to the Midland grinding plant for further processing. Products from the Midland plant go to glass, ceramic, chemical and other industries in Ontario.

The Midland plant has experienced difficulties from the start with crushing, grinding and classification circuits, the principal problem being the production of an unacceptable percentage of fines. The fines must be removed to meet glass-grade specifications and research into uses for the large volume of fines is actively being pursued. Modification of the circuits has been successful in improving overall recovery and physical specifications of the glass sand product. Additional process changes during the year have increased sand recovery and it is expected that sand sales will improve significantly during 1977. Reserves are reported to be 13 134 000 tonnes. In 1976 production was 410 000 tonnes (exclusive of metallurgical flux), an increase of 16 per cent, largely due to increased deliveries to the United States ferrosilicon market. Inco Limited (Inco) and Falconbridge Nickel Mines Limited together used 745 000 tonnes of silica for smelter flux.

Manitoba. Steel Brothers Canada Ltd. quarries friable sandstone of the Winnipeg Formation at Black Island in Lake Winnipeg. The sandstone is then barged to the company's processing plant at Selkirk where it is washed, sized and packaged for sale. The company provides silica sand for a large portion of the western Canadian market. Silica sand suitable for the manufacture of glass containers is shipped to Alberta. The majority of the remaining production is consumed in the Manitoba market, largely as foundry sand. The company formerly quarried quartzite and sand for Inco's smelter at Thompson, Manitoba, for use as metallurgical flux. Inco now manages these facilities. Manitoba's output declined almost 30 per cent to 442 000 tonnes in 1976 as a result of a glass plant strike and reduced smelter flux requirements.

Saskatchewan. Hudson Bay Mining and Smelting Co., Limited obtains silica for smelter flux from Pleistocene glacial sand deposits in Saskatchewan, adjacent to its operations at Flin Flon, Manitoba. Production in 1976 was 102 000 tonnes.

Alberta. Sil Silica Ltd. quarries Pleistocene dune sands at Bruderheim, 65 kilometres northeast of Edmonton. A washing and flotation plant upgrades material running 93 per cent silica, 3 per cent alumina, 1 per cent clay and 0.75 per cent iron oxide, to products suitable for fibreglass manufacture, sand blasting and foundry use. Since operations started in 1971 capacity has tripled to more than 60 000 tonnes a year. Reserves are adequate for many years.

British Columbia. In August 1968 Pacific Silica Limited ceased production of silica for ferrosilicon and silicon carbide at its deposit near Oliver, British Columbia. Stucco dash and roof chips are being produced from existing stockpiles. Production in 1976 was 31 000 tonnes.

Uses and specifications

The principal uses of lump silica, silica sand and crushed quartzite, together with specifications by consuming industry, are as follows:

Lump silica. *Silica flux.* Massive quartz, quartzite, sandstone and unconsolidated sands are used for flux in smelting base-metal ores where iron and basic oxides are slagged as silicates. Because free silica is the active slagging agent, the free silica content should be as high as possible. Minor amounts of impurities such as iron and alumina are tolerable. Lump silica used as a flux is usually minus one-plus 5/16 inch in size.

Silicon and silicon alloys. Lump quartz, quartzite and well-cemented sandstones are used in the manufacture of silicon, ferrosilicon and other silicon alloys. Lump silica ¾ to 5 inches in size, obtained by crushing quartzite or indurated sandstone, is used in the manufacture of ferrosilicon. Chemical specifications are: silica, 98.0 per cent, alumina (Al_2O_3), less than 1.0 per cent; iron (Fe_2O_3) plus alumina, not over 1.5 per cent; lime and magnesia, each less than 0.2 per cent. Phosphorus and arsenic should be absent.

Silica brick. Quartz and quartzite crushed to minus 8 mesh are used in the manufacture of silica brick for high-temperature refractory furnaces. Chemical specifications for this use are: silica, 96 to 98 per cent;

Table 2. Canada, silica production and trade, 1965, 1970, 1974-76

	Production	Imports		Exports	Consumption
Year	Quartz and[1] Silica Sand	Silica Sand	Silex or Crystallized Quartz	Quartzite	Quartz and Silica Sand
			(tonnes)		
1965	2 207 802	757 300	4 630	101 181	2 863 498
1970	2 937 498	1 176 199	186	58 917	3 979 305
1974	2 505 670	955 934	1 671	143 812	3 427 353[r]
1975	2 491 715	1 044 160	1 550	39 977	3 510 818
1976[p]	2 376 000	1 342 458	863	47 943	. .

Source: Statistics Canada.
[1]Includes silica to make silica brick.
[p]Preliminary; . . Not available; [r]Revised.

alumina, less than 0.1 per cent; combined iron and alumina, less than 1.5 per cent. Other impurities such as lime and magnesia should be low.

Aggregate. Crushed and sized quartz and quartzite are used as exposed aggregate in precast concrete panels for buildings, slabs, sidewalks and for other decorative landscape purposes.

Other uses. Lump quartz and quartzite are used as lining material in ball and tube mills and as lining and packing for acid towers. In some instances, naturally occurring quartzitic pebbles are used as grinding media in the crushing of various nonmetallic ores.

Silica sand. *Glass.* High-purity, natural-occurring sand or material produced by crushing quartzite or sandstone is used in the manufacture of glass. Minor amounts of certain elements are particularly objectionable because they act as powerful colourants. For example, chromium should not exceed six parts per million and cobalt not over two parts per million. Glass fibre optics technology, developing over the last few years, promises to become important in communications and could displace copper cable in several applications.

Silicon carbide. Silica sand used in the manufacture of silicon carbide should have a silica content of at least 99 per cent. Iron and alumina should be less than 0.1 per cent each; lime, magnesia and phosphorus should be absent. Sand should be plus 100 mesh, with the bulk of it plus 35 mesh.

Hydraulic fracturing. Sand is used in the hydraulic fracturing of oil-bearing strata to increase open-pore spaces, thus increasing the productivity of the oil well. Sand utilized for this purpose should be clean and dry, have a high compressive strength, be free of acid-consuming constituents and have a grain size between 20 and 35 mesh. Grains should be well-rounded to facilitate placement in the formation in order to provide maximum permeability.

Foundry sand. Naturally occurring sand or material produced by crushing friable sandstone is used in the foundry industry for moulding. For foundry purposes, the chemical composition of the sand is not as important as its physical properties. For the end-use, a highly refractory sand, having rounded grains with frosted or pitted surfaces, is preferred. Grain sizes vary between 20 and 200 mesh. Rounded grains are preferable to angular fragments because they allow maximum permeability of the mould and maximum escape of gas during casting.

Sodium silicate. Sand for the manufacture of sodium silicate should contain more than 99 per cent silica, less than 0.25 per cent alumina, less than 0.05 per cent lime and magnesia combined, and less than 0.03 per cent iron (Fe_2O_3). All sand should be between 20 and 100 mesh.

Other minor uses. Coarsely ground, closely sized quartz, quartzite, sandstone and sand are used as abrasive grit in sandblasting and in the manufacture of sandpaper. Various grades of sand are used as filtering media in water-treatment plants; silica is also required in portland cement manufacture if there is insufficient silica in the limestone or in other raw material used in the process.

Silica flour. Silica flour, produced by fine-grinding quartzite, sandstones and lump quartz, is used in the ceramics industry for enamel frits and pottery flint. For use in enamels, the silica flour must be over 97.5 per cent silica, with alumina (Al_2O_3) less than 0.5 per cent and iron (Fe_2O_3) less than 0.2 per cent. Silica flour is also used as an inert filler in rubber and asbestos cement products, as an extender in paints and as an abrasive agent in soaps and scouring pads. It is used

Table 3. Canada, available data on consumption of silica, by industries, 1974-75

	1974[r]	1975
	(tonnes)	
Smelter flux[1]	1 259 902	1 496 195
Glass manufacture (incl. glass fibre)	726 098	684 210
Foundry sand	659 083	677 886
Ferrosilicon	155 678	68 140
Artificial abrasives	151 707	137 632
Metallurgical use	58 714	72 843
Asbestos products	39 600	42 732
Chemicals	26 123	16 977
Fertilizer, stock, poultry feed	17 560	14 939
Concrete products	14 281	11 168
Gypsum products	8 939	8 659
Other[2]	309 668	279 437
Total	3 427 353	3 510 818

Source: Statistics Canada. Classification of data by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Producers' shipments of quartz and silica for flux purposes. [2]Includes ceramic products, soaps, frits and enamels, paper and paper products, roofing, refractory brick mixes, silica brick and other minor uses.
[r] Revised.

increasingly in autoclave-cured concrete products such as building blocks and panels, approximately 45 pounds of silica flour being used for each 100 pounds of portland cement consumed.

Quartz crystal. Quartz crystal with desirable piezo-electric properties is used in radio-frequency control, radar and other electronic devices. Natural crystal for this purpose must be perfectly transparent and free from all impurities and flaws. The individual crystals should weigh 100 grams or more and measure at least two inches in length and one inch or more in diameter. Much of the world's crystal requirement has been met by natural crystal from Brazil; however, natural crystal is being rapidly replaced by excellent-quality, synthetic crystal grown in the laboratory from quartz "seed". Artificial quartz crystals are oriented for the cutter prior to delivery. The high degree of purity permits product yields at least four times that of natural quartz crystal.

There is no production of quartz crystal in Canada, and only a small demand exists. Domestic requirements are met mainly by imports, chiefly from the United States, with minor amounts from Brazil. Quartz Crystals Mines Limited, Toronto produced minor amounts from an occurrence near Lyndhurst, Ontario, several years ago.

A quartz-crystal stockpile of 165.8 tonnes was sold by the Canadian Government during 1974.

Outlook

The economic downturn which started in late 1974 continued through 1975 and showed little improvement in 1976. Canadian production of silica decreased 5 per cent in 1976, largely as a result of decreased output in Manitoba, although with a 30 per cent increase in imports of silica sand, overall apparent consumption was up an estimated 5 per cent.

Expected increases in output of silica sand from Indusmin's operations in both Ontario and Quebec, Sil Silica's operation in Alberta in response to growing demand for fibreglass insulation, and Steel Brother's plant in Manitoba, should boost Canada's silica production to the 1974 level of output. Although silica reserves are large and there is scope for displacing imports, full-capacity utilization and further expansion in the industry must await significant economic recovery.

Tariffs

Canada

Item No.		
29500-1	Ganister and sand	free
29700-1	Silex or crystallized quartz, ground or unground	free

United States

Item No.		(¢ per lt)
513.11	Sand containing 95% or more silica, and not more than 0.6% of oxide of iron	25
513.14	Sand, other	free
514.91	Quartzite, whether or not manufactured	free
523.11	Silica, not specially provided for	free

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), T.C. Publication 749.

Silicon, Ferrosilicon, Silicon Carbide and Fused Alumina

ALBERT BOUCHARD

The world market for silicon metal is closely connected with the aluminum market, since silicon metal is alloyed with aluminum in proportions which range as high as 25 per cent silicon per tonne* of finished product. In 1976, following a period of recession, the demand for aluminum began to recover. This gave new encouragement to silicon metal producers, but the recovery had no tangible effects in 1976 and recessionary conditions prevailed throughout the year in the silicon metal market.

The situation was fairly similar for ferrosilicon since it depends almost entirely on the steel industry, which uses an average of 2.5 to 3 kilograms of silicon per tonne of steel. Since recovery in the steel sector in 1976 was relatively slow, with the exception of the automobile industry it was natural that the ferrosilicon industry would be in the same position. Thus, most of the world's silicon producers underwent a significant decline in production, many of them operating at only 50 to 70 per cent capacity for most of the year.

The demand for silicon carbide in 1976 was stronger than for the other two silicon products, since silicon carbide, like most other abrasives, is not dependent on one particular industrial sector, but on industry in general. Consequently, the market for silicon carbide was relatively stable, both in Canada and worldwide.

Canada

The production of silicon metal, ferrosilicon, silicon carbide and fused alumina is energy-intensive. Therefore, this type of industry is usually located in areas where electric energy is abundantly available and inexpensive. Canada is an important producer and exporter of these products, with plants located in Quebec and Ontario. There are three producers of ferrosilicon in the country: Union Carbide Canada Limited, with plants at Beauharnois and Chicoutimi, Quebec; Chromasco Limited, with a plant at Beauharnois, Quebec; and S.K.W. Electro-Metallurgy Canada Ltd., with a plant at Bécancour, Quebec. Union Carbide Canada Limited and S.K.W. Electro-Metallurgy Canada Ltd. also produce silicon metal, which is used in the aluminum, copper and steel industries.

S.K.W. Electro-Metallurgy Canada Ltd. entered the Canadian market in 1976 as a new producer in silicon metal and ferrosilicon, with a $50 million plant in the Bécancour area of Quebec. The company is a subsidiary of S K W — Trostberg of West Germany (85 per cent) and A/S Ila og Lilleby Smelteverker of Norway (15 per cent). The plant operates three electric furnaces, two 20-megawatt and one 30-megawatt, with an annual production capacity of 27 200 tonnes of 50 per cent and 75 per cent ferrosilicon, and 22 700 tonnes of silicon metal. Production began in July 1976. Only a small percentage of the total production is likely to be used locally, the main markets being the United States, Germany and Japan.

The demand for Canadian ferrosilicon was low in 1976. As a result, Union Carbide Canada Limited operated at only 50 per cent capacity. Chromasco was affected less, since most of its production goes to its Haley, Ontario plant where it is used to produce magnesium, which was in strong demand in 1976. Thus, Chromasco operated at about 85 per cent capacity over the year.

Union Carbide Canada Limited was still the only Canadian producer of silicon metal in 1976, since S.K.W. Electro-Metallurgy Canada Ltd. was producing only ferrosilicon at its new plant. Since Union Carbide is the main supplier of silicon metal to the Aluminum Company of Canada Limited, its production was affected significantly by the long Alcan strike in 1976.

The production of silicon carbide in Canada is concentrated in Quebec and Ontario. The producers are: Canadian Carborundum Company, Limited, Shawinigan, Quebec; Norton Company, Cap-de-la-Madeleine, Quebec and Niagara Falls, Ontario; Electro Refractories & Abrasives Canada Ltd., Cap-de-la-

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, ferrosilicon, silicon carbide and some other ferroalloys[1], exports and imports, 1975-76

	1975		1976^p	
	(tonnes)	($)	(tonnes)	($)
Imports				
Ferrosilicon				
United States	17 104	5 175 000	30 008	9 794 000
United Kingdom	10 417	2 456 000	3 405	1 239 000
Brazil	—	—	270	52 000
Dominican Republic	158	106 000	88	52 000
Jamaica	—	—	61	46 000
Angola	721	140 000	187	40 000
New Zealand	—	—	49	40 000
Taiwan	—	—	28	26 000
Other countries	413	147 000	123	35 000
Total	28 813	8 024 000	34 219	11 324 000
Silicon carbide, crude and grains				
United States	77 719	17 104 000	83 848	22 857 000
United Kingdom	456	178 000	1 852	580 000
Brazil	224	103 000	293	131 000
Japan	—	—	255	102 000
Greece	176	40 000	147	54 000
West Germany	18	7 000	—	—
Total	78 593	17 432 000	86 395	23 724 000
Ferroalloys, nes				
United States	580	661 000	1 012	1 836 000
Argentina	92	145 000	80	318 000
Japan	—	—	46	227 000
India	—	—	34	203 000
Netherlands	97	165 000	36	179 000
United Kingdom	35	165 000	357	106 000
Poland	17	81 000	—	—
Australia	52	66 000	—	—
Colombia	5	23 000	—	—
Other countries	367	70 000	166	26 000
Total	1 245	1 376 000	1 731	2 895 000
Exports				
Ferrosilicon				
United States	19 172	9 017 000	7 992	5 533 000
Yugoslavia	3 769	3 413 000	1 257	713 000
Norway	2 208	2 121 000	615	473 000
France	260	244 000	275	225 000
Sweden	—	—	208	164 000
Chile	—	—	37	12 000
Spain	577	657 000	—	—
Other countries	366	213 000	—	—
Total	26 352	15 665 000	10 384	7 120 000

Table 1. (concl'd)

	1975		1976ᵖ	
	(tonnes)	($)	(tonnes)	($)
Silicomanganese including silico spiegel				
United States	5 731	3 230 000	4 949	2 583 000
Norway	—	—	3 587	2 013 000
Brazil	—	—	2 063	949 000
France	—	—	1 332	656 000
Other countries	—	—	91	49 000
Total	5 731	3 230 000	12 022	6 250 000
Ferroalloys, nes				
Dominican Republic	4 746	8 090 000	12 578	19 305 000
Greece	—	—	4 490	6 066 000
United States	2 755	3 171 000	3 225	3 788 000
Brazil	228	1 059 000	361	1 863 000
South Africa	—	—	3 209	1 477 000
France	1 033	1 273 000	883	952 000
Japan	—	—	162	167 000
West Germany	78	109 000	29	40 000
Other countries	40	92 000	35	53 000
Total	8 880	13 794 000	24 972	33 711 000

Source: Statistics Canada.
[1]Other important ferroalloys are discussed in the manganese, nickel and titanium reviews for 1976.
nes Not elsewhere specified; — Nil; ᵖPreliminary.

Madeleine, Quebec; General Abrasive (Canada) Limited, Niagara Falls, Ontario; and the Exolon Company of Canada, Ltd., Thorold, Ontario.

The demand for silicon carbide was relatively strong throughout the year and all the companies except the Norton Company of Canada, Limited, in Niagara Falls, operated at full capacity. The entire Canadian production is exported to the United States, where the crude material is crushed, separated and screened. A small portion of the refined material comes back to Canada to be used in the manufacture of bonded abrasives, such as abrasive wheels, and coated abrasives, such as sandpaper. The raw materials used for the production of silicon carbide are petroleum coke and silica sand. In 1975, the most recent year for which statistics are available, Canada's shipments of crude silicon carbide amounted to 89 346 tonnes, valued at $24 597 000 or about $275 per tonne, while Canadian consumption of refined silicon carbide, used in the manufacture of abrasive products, totalled 1 661 tonnes, valued at $1 068 000, or about $643 per tonne. The value of Canada's shipments of abrasive wheels and abrasive cloth was estimated at $17 583 000 and $10 308 000, respectively, while shipments of abrasive paper were valued at $13 639 000 and shipments of other coated abrasive products at $4 235 000. The producers of abrasive wheels are all located in Ontario, as follows:

Table 2. Ferrosilicon production and trade, 1974

	Production	Imports	Exports
	(tonnes, gross weight)		
Austria	. .	10 969	. .
Luxembourg and Belgium	. .	41 352	. .
Canada		10 559	46 001
France	. .	. .	106 213
West Germany	. .	133 977	13 845
India	30 468	. .	996
Italy	. .	51 776	. .
Japan	. .	70 658	22 574
Norway	. .	. .	308 848
Spain	. .	. .	15 365
Sweden	51 813	24 704	32 554
United Kingdom	. .	77 044	3 609
United States	591 317	129 227	5 964
U.S.S.R.	. .	. .	151 400
Yugoslavia	. .	. .	57 003

Sources: *Metal Bulletin*, Handbook 1976; for Canada, Statistics Canada; for U.S., Bureau of Mines *Minerals Yearbook*, Preprint 1975.
. . Not available.

Producer	Location
Dresser Bay State Abrasives Canada Limited	Brantford
Unicorn Abrasives of Canada, Limited	Brockville
Norton Company of Canada, Limited	Hamilton
The Wright Abrasives Limited	Hamilton
Canadian Grinding Wheel Company Limited	Hamilton
Midwest Abrasives Ltd.	Strathroy

In 1976 Simonds Abrasive Division, Wallace-Murray Canada, Limited sold its plants in Arvida, Quebec and Brockville, Ontario to Unicorn Industries of England, the third-largest producer of abrasives in the world. The new company operates under the name of Unicorn Abrasives of Canada, Limited.

Table 3. Canada, ferrosilicon production[1], 1967-75

	Ferrous industry[2]	Other industries[3]	Total
	(tonnes)		
1967	38 453	11 439	49 892
1968	71 175	9 428	80 603
1969	70 386	11 430	81 816
1970	78 338	8 087	86 425
1971	65 303	13 068	78 371
1972	69 878	12 065	81 943
1973	68 172	21 048	89 220
1974	66 940	28 163	95 103
1975	41 443	15 922	57 365

Source: Statistics Canada.
[1]Producers' shipments; [2]Estimated by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa. [3]Principally abrasives industry.

World developments

In 1976 a number of expansion and construction projects were begun, and others completed, throughout the world. Several American plants added new furnaces. The Foote Mineral Company of Graham, Virginia and Ohio Ferro-Alloys Corp. of Philo, Ohio were thus able to increase their ferrosilicon production capacity. Other companies, such as Globe Metallurgical Div. of Interlake, Inc. of Selma, Alabama, Northwest Alloys, Inc. of Addy, Washington and Airco, Inc. of Niagara Falls, New York also increased their silicon metal production capacity. In addition, Ohio Ferro-Alloys began production of silicon metal at its new plant in Montgomery, Alabama.

In France the Compagnie Universelle d'Acétylène et d'Electro-Métallurgie will build a new plant at Dunkirk, with an annual capacity of 50 000 tonnes. The plant will produce mainly 75 per cent ferrosilicon and should begin operating early in 1978.

The Icelandic government and the Norwegian Company, Elkem-Spigerverket, Norway's largest producer of ferroalloys, signed a contract for the construction and operation of a new plant in the Hvalfjordur area of southern Iceland, with an annual capacity of 50 000 tonnes of ferrosilicon. The new company, Icelandic Alloys, Ltd., is owned 55 per cent by the Icelandic government and 45 per cent by Elkem, which was invited to participate in the project following the withdrawal of Union Carbide Corporation. The first furnace should go into operation in January 1979 and the second about 18 months later. In Mexico, the Carborundum Company Limited is in the process of building a plant with an initial capacity of 10 000 tonnes

Table 4. Canada, consumption, exports and imports of ferrosilicon, 1967-76

	Consumption	Exports		Imports	
	(tonnes)	(tonnes)	($)	(tonnes)	($)
1967	31 557	38 038	4 189 328	19 722	3 534 000
1968	46 674	42 833	5 424 665	8 905	2 615 000
1969	46 028	43 998	5 257 000	8 210	2 010 000
1970	50 556	45 345	8 284 000	9 477	2 386 000
1971	39 571	48 217	8 699 000	9 417	2 679 000
1972	42 270	48 349	7 188 000	8 676	2 663 000
1973	55 811	46 574	6 836 000	12 920	4 135 000
1974	59 661	46 002	9 316 000	10 560	5 293 000
1975	54 904	28 813	8 024 000	26 353	15 665 000
1976[p]	. .	34 219	11 324 000	10 384	7 120 000

Source: Statistics Canada.
[p]Preliminary; . . Not available.

Table 5. Canada, manufacturers' shipments of crude silicon carbide, 1966-75

	(tonnes)	($)
1966	98 295	14 777 000
1967	87 283	13 564 000
1968	99 042	16 192 000
1969	98 156	15 815 000
1970	104 113	17 653 000
1971	93 879	15 798 000
1972	104 152	17 880 000
1973	107 303	18 985 000
1974	102 299	21 908 000
1975		24 597 000

Source: Statistics Canada.

Table 7. Canada, manufacturers' shipments of crude fused alumina, 1966-75

	(tonnes)	($)
1966	166 848	21 036 000
1967	137 268	17 620 000
1968	128 078	17 337 000
1969	149 071	19 993 000
1970	131 364	18 088 000
1971	112 935	16 159 000
1972	140 540	21 198 000
1973	155 342	25 986 000
1974	174 108	34 679 000
1975	110 736	26 162 000

Source: Statistics Canada.

of silicon carbide per year. Carborundum has a 49 per cent share in the project, the Mexican government 40 per cent and some Mexican companies 11 per cent. The plant will be located in Jaltipan and should begin production early in 1978.

Table 6. Canada, exports of silicon carbide, 1966-76

	(tonnes)	($)
1966	89 702	12 831 523
1967	79 076	11 461 930
1968	93 372	14 690 146
1969	93 895	14 974 000
1970	96 159	15 976 000
1971	85 148	13 593 000
1972	94 700	15 051 000
1973	92 984	15 666 000
1974	91 819	15 887 000
1975	78 593	17 432 000
1976^p	86 395	23 724 000

Source: Statistics Canada.
^{p} Preliminary.

Uses

Silicon, in the form of ferrosilicon and silicon metal, is the most widely used deoxidizer in the manufacture of alloy steels and carbon steel. Silicon alloys are ferrosilicon, silvery pig iron, silicomanganese, ferroaluminum-silicon, ferrochrome-silicon, ferromanganese-silicon, calcium-silicon, calcium-manganese-silicon, barium-silicon, ferrozirconium-silicon and zirconium-silicon. All these alloys are used in the metallurgical industry. More ferrosilicon is produced than any of the other alloys. Silicon metal is alloyed with steel, aluminum and copper and is also used in the production of silicones, silicates and other chemical products. Purified silicon metal is used as a semiconductor in electronic circuits, but only very small quantities are needed. Silicon carbide is essentially a synthetic abrasive but it is sometimes used in small quantities as a deoxidizer in iron metallurgy.

Table 8. Canada, exports of fused alumina crude, 1967-76

	(tonnes)	($)
1967	151 666	19 482 573
1968	143 896	19 385 395
1969	167 791	24 508 870
1970	152 572	23 234 285
1971	122 652	19 096 000
1972	160 147	24 967 000
1973	171 324	29 923 000
1974	184 182	33 839 000
1975	127 444	26 602 000
1976^p	154 002	38 844 000

Source: Statistics Canada.
^{p} Preliminary.

Outlook

The demand for silicon metal and ferrosilicon should increase in 1977 since a greater demand is expected for aluminum and steel.

Prices published by "Metals Week" in December 1975 and 1976

		1975	1976
		(U.S.¢)	(U.S.¢)
Ferrosilicon, pound contained silicon, fob shipping point, freight equalized to nearest main producer, carload lots, lump bulk			
High-purity	(% Si)		
	75	36.5	37.0
	85	. .	. .
	90	. .	. .
Regular	50	32.5	34.5
Silicon metal, pound contained silicon, fob shipping point, freight equalized to nearest main producer, carload lots, lump bulk			
(% max. Fe)	(% max. Ca)		
0.35	0.07	46.4	46.4-49.4
0.50	0.07	. .	. .
1.00	0.07	42.25	42.5-45.5

Price published by "American Metal Market" in December 1975 and 1976

	1975	1976
	(U.S. ¢)	(U.S. ¢)
SMZ alloy: 60-65% Si, 5-7% Mn 5-6% Zr, 15-ton lots, per pound of alloy	33.0	35.50
Calcium-silicon and calsibar alloy, fob producer, 15-ton lots, per pound	57.0	57.0
Electric furnaces silvery pig iron, fob Niagara Falls	(U.S. $)	(U.S. $)
16% Si, per ton	190.00	190.00
22% Si, per gross ton	212.00	212.00

Prices published by "Industrial Minerals"

(long ton, cif main Europe port)

	Dec. 1975	Dec. 1976
	(£)	(£)
Fused alumina, 8-220 mesh, cif		
Brown, min. 94% Al_2O_3	190-210	250-260
White, min. 99.5% Al_2O_3	235-250	300-320
Silicon carbide, 8-220 mesh, cif		
Black, about 99% SIC	375-380	450-460
Green, over 99.5% SIC	475-480	570-580

. . Not available.

Tariff Profile

Canada

Item No.		British Preferential	Most favoured Nation	General
		(¢)	(¢)	(¢)
37502-1	Silicomanganese — alloys of manganese and iron containing more than 1%, by weight, of silicon per pound or fraction thereof, on the manganese contained therein.	free	0.75	1.75
37503-1	Ferrosilicon being an alloy of iron and silicon containing 8% or more, by weight, of silicon and less than 60%, per pound or fraction thereof, on the silicon contained therein.	free	free	1.75
37504-1	Ferrosilicon being an alloy of iron and silicon containing 60% or more, by weight, of silicon and less than 90%, per pound or fraction thereof, on the silicon contained therein.	free	0.75	2.75
37505-1	Ferrosilicon being an alloy of iron and silicon containing 90% or more, by weight, of silicon per pound or fraction thereof, on the silicon contained therein.	free	2.50	5.50
92804-1	Silicon metal	10%	15%	25%
92815-4	Silicon sulphide	10%	15%	25%

United States

Item No.		General
		(¢)
519.21	Crude silicon carbide	free
519.37	Silicon carbide in grains, ground, pulverized or refined, per pound	0.40
607.50	Ferrosilicon, per pound Si content, containing over 8% but not over 60% by weight of silicon	free
607.51	Ferrosilicon, per pound Si content, containing over 60% but not over 80% by weight of silicon	0.50
607.52	Ferrosilicon, per pound Si content, containing over 80% but not over 90% by weight of silicon	1.00
607.53	Ferrosilicon, per pound Si content, containing over 90% by weight of silicon	2.00
607.55	Ferrosilicon chromium	10%
607.57	Ferrosilicon manganese, per pound Mn content	0.46 + 3.5%

Japan

Item No.		General	G.A.T.T.	Preferential
		(%)	(%)	(%)
28-04	Silicon — Single crystal	16	12	free
	— Other	12	6	free
28-56	Silicon carbide	12	6	free
68-06	Abrasive paper	12	—	free
73-02	Ferrosilicon	8	4	free
	Silicochrome	—	4	—

European Economic Community

Item No.		Autonomous	Conventional
		(%)	(%)
28.13	Silicon dioxide	10	6.4
73.02	Ferrosilicon	10	10 (limit 20,000 tonnes)
	Ferrosilicomanganese	6	5.5 (limit 50,000 tonnes)
	Ferrosilico-chrome	7	7

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States, Annotated (1976), TC Publication 749. For Japan, Customs Tariff Schedules of Japan, 1976, Japan Tariff Association. For E.E.C., Official Journal of European Communities, Vol. 19, No. L314, 1976.

Silver

J.G. GEORGE

Canada's primary* production of silver in 1976, estimated at 1 271 728 kilograms** (40 887 000 ounces**), was 37 086 kilograms (1.19 million ounces) more than in 1975. The increase was mainly attributable to greater output at the silver-copper properties of Echo Bay Mines Ltd. and Terra Mining and Exploration Limited near Port Radium in the Northwest Territories. Greater output of several base-metal mines which produce silver as a byproduct also contributed to the higher Canadian output, particularly that of the Kidd Creek mine of Texasgulf Canada Ltd. near Timmins, Ontario and of Heath Steele Mines Limited in New Brunswick. Declines in output in New Brunswick, Manitoba and the Yukon Territory were more than offset by increases in the other silver-producing provinces and the Northwest Territories. Ontario was again, by far, the leading silver-producing province, primarily because of the substantial byproduct silver produced at the Kidd Creek base-metal mine of Texasgulf Canada Ltd. The value of Canadian silver production was $175.1 million, or $3.7 million less than in 1975 because of lower prices.

Canada's exports of silver in ores and concentrates and as refined metal totalled 1 374 171 kilograms in 1976, 189 195 kilograms more than the corresponding amount in 1975. The United States continued to be the major market, accounting for almost 90 per cent of Canada's total exports. Canadian imports of refined silver declined from 420 078 kilograms in 1975 to 59 627 kilograms in 1976. Most of the imports came from the United States, with minor quantities coming from Peru and the United Kingdom.

Canadian consumption of silver for both industrial and coinage uses was 550 667.0 kilograms in 1976, compared with 642 088.7 kilograms in 1975. These are official figures published by Statistics Canada, but are incomplete. A reduction in the amount of silver used in minting Olympic coins in 1976 was the main reason for the decrease.

Domestic production

Mine production. The principal source of silver was again base-metal ores, which accounted for over 96 per cent of total production. The major portion of the remaining four per cent came from silver-cobalt ores mined in the Cobalt district of northern Ontario, and the balance was byproduct recovery from lode and placer gold ores. The principal mine producers of silver in Canada are listed in Table 5, while the map, "Silver Producers in Canada 1976", on Page 24 shows their approximate locations. The four largest producers in order of output were: Texasgulf Canada Ltd. in Ontario, Brunswick Mining and Smelting Corporation Limited in New Brunswick, Cominco Ltd. (Sullivan mine) in southeastern British Columbia, and Mattabi Mines Limited in northwestern Ontario. Base-metal ores mined by these four producers accounted for almost 43 per cent of total Canadian silver production. The largest producer in the Cobalt area of northern Ontario was Teck Corporation Limited, Silverfields Division, with output of 17 387 kilograms of silver contained in ores and concentrates produced.

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*As reported by Statistics Canada and defined in Footnote 1 of Table 1.
**In this review the term "ounce" refers to the troy ounce, and the conversion factor used for converting ounces to grams is 1 troy ounce = 31.1034768 grams.

Metal Production. Production of refined silver in 1976 at the six Canadian primary silver refineries was as follows:

	Production[1] Refined Silver	Annual Rated Capacity[2]
	(kilograms)	
Brunswick Mining and Smelting Corporation Limited, Smelting Division, Belledune, New Brunswick	93 421[3]	108 900
Canadian Copper Refiners Limited, Montreal East, Quebec	699 859	777 600
Royal Canadian Mint, Ottawa, Ontario	5 889[4]	217 700[5]
Canadian Smelting & Refining (1974) Limited, Cobalt, Ontario	12 633	186 600[7]
Inco Metals Company, Copper Cliff, Ontario	37 013[6]	. .
Cominco Ltd., Trail, British Columbia	293 306	373 200

Sources: Reports of companies and of the Royal Canadian Mint.
[1]Production of refined silver includes silver produced or derived from domestic and imported ores and concentrates as well as secondary materials. The largest portion of such refined silver was, however, derived from domestic ores and concentrates. [2]As at December 31, 1976. [3]All the refined silver bullion produced by Brunswick Mining and Smelting Corporation Limited was shipped to Canadian Copper Refiners Limited at Montreal East, Quebec, for further refining; and the 699 859 kilograms of silver reported as production for Canadian Copper Refiners Limited (CCR) includes all of that silver bullion produced by Brunswick and refined by CCR in 1976. [4]Silver derived from refining gold bullion. [5]Total capacity for producing refined gold and silver, of which about 10 per cent is silver. [6]Silver delivered to markets. [7]Up to this amount, depending on nature of materials processed.
. . Not available.

Canadian Copper Refiners Limited at Montreal East, Quebec, was again Canada's largest producer of refined silver, recovering it mainly from the treatment of anode and blister copper and the further refining of lower-grade silver bullion. The silver refinery of Cominco Ltd. at Trail, British Columbia, was the second-largest producer, recovering byproduct silver in the processing of its own, as well as custom, lead and zinc ores and concentrates. Other producers of refined silver were Inco Metals Company at Copper Cliff, Ontario (from nickel-copper concentrates); and the Royal Canadian Mint at Ottawa, Ontario (from gold bullion). At Cobalt, Ontario, Canadian Smelting & Refining (1974) Limited recovered silver in processing silver-cobalt ores and concentrates produced in that area of northern Ontario. At Belledune, New Brunswick, Brunswick Mining and Smelting Corporation Limited, Smelting Division, recovered byproduct silver from lead concentrates treated in a blast furnace.

At its electronic materials plants at Trail, B.C., Cominco Ltd. also produced high-purity silver metal with metallic impurities totalling one part per million or less. This specialty metal product was manufactured mainly for applications in the electronics industry such as solder preforms, brazing preforms and lead wire.

Table 1. Canada, silver production, trade and consumption, 1975-76

	1975		1976^p	
	(grams)	($)	(grams)	($)
Production[1]				
By province and territories				
Ontario	463 694 924	67 176 070	486 552 000	67 000 000
British Columbia	196 638 482	28 487 265	254 955 000	35 108 000
New Brunswick	157 049 883	22 752 011	156 108 000	21 497 000
Quebec	105 662 368	15 307 441	114 678 000	15 794 000
Northwest Territories	61 319 167	8 883 385	108 085 000	14 885 000
Yukon Territory	196 943 109	28 531 397	97 634 000	13 446 000
Manitoba	31 153 211	4 513 205	27 713 000	3 817 000
Newfoundland	13 841 172	2 005 188	15 925 000	2 194 000
Saskatchewan	8 338 687	1 208 036	10 078 000	1 387 000
Alberta	622	90	—	—
Total	1 234 641 625	178 864 088	1 271 728 000	175 128 000

Table 1. (concl'd)

	1975		1976[p]	
	(grams)	($)	(grams)	($)
Production[1] (cont'd)				
By source				
Base-metal ores	1 203 903 272	174 410 987	1 225 401 000	168 742 000
Gold ores	7 073 117	1 024 691	7 332 000	1 014 000
Silver-cobalt ores	23 593 853	3 418 070	38 902 000	5 359 000
Placer gold ores	71 383	10 340	93 000	13 000
Total	1 234 641 625	178 864 088	1 271 728 000	175 128 000
Refined silver[2]	901 845 994	. .	1 023 928 000	. .
Exports				
In ores and concentrates				
United States	231 433 475	27 445 000	272 358 000	32 594 000
Japan	140 815 921	19 710 000	88 381 000	11 546 000
Germany West	45 413 471	4 488 000	28 066 000	2 103 000
Belgium and Luxembourg	27 920 938	2 434 000	24 218 000	1 707 000
U.S.S.R.	—	—	2 904 000	237 000
Sweden	3 333 484	492 000	1 434 000	187 000
Others	22 493 102	1 533 000	9 397 000	436 000
Total	471 410 391	56 102 000	426 758 000	48 810 000
Refined Metal				
United States	701 942 487	100 062 000	939 192 000	129 060 000
Trinidad-Tobago	1 913 735	289 000	3 160 000	441 000
Jamaica	3 115 760	521 000	2 512 000	368 000
United Kingdom	3 006 151	449 000	1 158 000	119 000
South Korea	—	—	499 000	67 000
Other	3 587 785	267 000	892 000	81 000
Total	713 565 918	101 588 000	947 413 000	130 136 000
Imports				
Refined metal				
United States	414 616 437	58 936 000	49 791 000	6 868 000
Peru	—	—	5 974 000	576 000
United Kingdom	4 981 595	747 000	2 726 000	413 000
Other	480 114	240 000	1 136 000	195 000
Total	420 078 146	59 923 000	59 627 000	8 052 000
Consumption, by use				
Sterling	50 556 587	. .	51 841 000[e]	. .
Silver alloys	91 828 536	. .	79 494 000[e]	. .
Wire rod	1 345 816	. .	2 489 000[e]	. .
Others[3]	498 357 790	. .	416 843 000[e]	. .
Total	642 088 729	. .	550 667 000[e]	. .

Sources: Statistics Canada; Royal Canadian Mint Annual Report, 1975.
[1]Includes recoverable silver in: ores, concentrates and matte shipped for export; crude gold bullion produced; blister and anode copper produced at Canadian smelters; base and other bullion produced from domestic ores. [2]From all sources, domestic and imported materials of both primary and secondary origin. [3]Includes sheet, partial coinage and miscellaneous uses.
[p]Preliminary; — Nil; . . Not available; [e]Estimated.

Table 2. Canada, silver production, trade and consumption, 1967-76

	Production		Exports			Imports,	Consump-tion[3]
	All Forms[1]	Refined[2] Silver	In Ores and Concentrates	Refined Silver	Total	Refined Silver	Refined Silver
				(grams)			
1967	1 039 412 069	642 552 917	323 706 884	427 227 249	750 934 133	167 457 138	453 383 189
1968	1 400 054 487	1 076 533 135	668 787 642	874 149 593	1 542 937 235	437 334 635	422 956 213
1969	1 353 963 613	1 203 036 449	680 638 254	1 078 013 443	1 758 651 697	596 215 860	178 753 796
1970	1 376 353 856	955 668 321	678 675 500	752 689 333	1 431 364 833	134 347 020	187 679 250
1971	1 431 493 042	638 995 924	795 085 083	566 125 921	1 361 211 004	22 482 066	219 309 246
1972	1 393 193 433	707 317 821	688 749 356	616 641 202	1 305 390 558	37 874 019	262 025 455
1973	1 477 029 123	796 139 491	814 975 134	712 421 808	1 527 396 942	272 304 283	529 090 108
1974	1 331 531 164	852 754 692	602 892 065	663 709 316	1 266 601 381	909 654 646	598 113 731[r]
1975	1 234 641 625	901 845 994	471 410 391	713 565 918	1 184 976 309	420 078 146	642 088 728
1976[p]	1 271 728 000	1 023 928 000	426 758 000	947 413 000	1 374 171 000	59 627 000	550 667 000[e]

Sources: Statistics Canada, Royal Canadian Mint Annual Report, 1976.
[1]Includes recoverable silver in: ores, concentrates and matte shipped for export; crude gold bullion produced; blister and anode copper produced at Canadian smelters; base and other bullion produced from domestic ores. [2]From all sources, domestic and imported materials of both primary and secondary origin. [3]In some cases includes only partial consumption for coinage.
[p]Preliminary; [e]Estimated; [r]Revised.

World production, consumption and economic factors

New production of silver in the noncommunist world in 1976, as estimated by Handy & Harman*, was 7 589.25 tonnes**, or 180.40 tonnes more than in 1975. In 1976 noncommunist world consumption for both industrial and coinage uses was 13 125.67 tonnes, compared with 12 270.32 tonnes in 1975. The gap between new production and consumption was 5 536.42 tonnes, or considerably more than the corresponding deficit of 4 861.5 tonnes in 1975.

Consumption of silver for coinage in the noncommunist world in 1976 was 839.79 tonnes, about 68.43 tonnes less than in 1975. Except for minor quantities used in 1971 in the minting of commemorative coins and in 1972 in the minting of silver dollars, silver had not been used in the production of Canadian coinage since 1968. On November 14, 1973, the Royal Canadian Mint struck the first new Olympic coin. It marked the beginning of production of coins containing 92.5 per cent silver to commemorate the Olympic Games held in 1976. The coins were of $5 and $10 face value and the total face value of all the coins issued could have been up to $450 million, as provided by legislation contained in a special Act of Parliament given Royal Assent July 27, 1973. It was originally planned that the total amount of silver involved in minting the Olympic coins could be up to 1 804 tonnes (58 million ounces) and that the total number of coins issued could exceed 60 million.

However, because of lower demand than anticipated, the total amount of silver used in minting the Olympic coins amounted to some 1 072.29 tonnes (34.475 million ounces). The overall program consisted of seven separate series of coins, with each series made up of four different coins, two of $5 face value and two of $10 face value, and with different designs for all 28 coins.

*_The Silver Market 1976_, compiled by Handy & Harman, a leading United States refiner and fabricator of precious metals, and a large consumer of silver.
**The term "tonne" refers to the metric ton of 2,204.62 pounds avoirdupois.

In 1976 the Royal Canadian Mint completed production of the seven series of Olympic silver coins. According to figures released by the Royal Canadian Mint, it produced the following quantities of Olympic coins:

	$5 Coins		$10 Coins		
	Number of Coins	Total Silver Content* in tonnes	Number of Coins	Total Silver Content* in tonnes	Total Silver Content* of both coins in tonnes
1973	543 098	12.19	537 898	24.17	36.36
1974	7 354 223	165.32	6 751 753	303.48	468.80
1975	3 970 000	89.24	4 952 433	222.63	311.87
1976	3 775 259	84.86	3 790 514	170.40	255.26
Total	15 642 580	351.61	16 032 598	720.68	1 072.29

*Silver contents calculated on basis of one $5 coin containing 22.48 grams (0.7227 ounce) of silver, and one $10 coin containing 44.95 grams (1.4453 ounces) of silver.

Although construction of the new Winnipeg, Manitoba, Division of the Royal Canadian Mint was not fully completed until the end of April 1976, the Winnipeg plant began commercial production in March 1975.

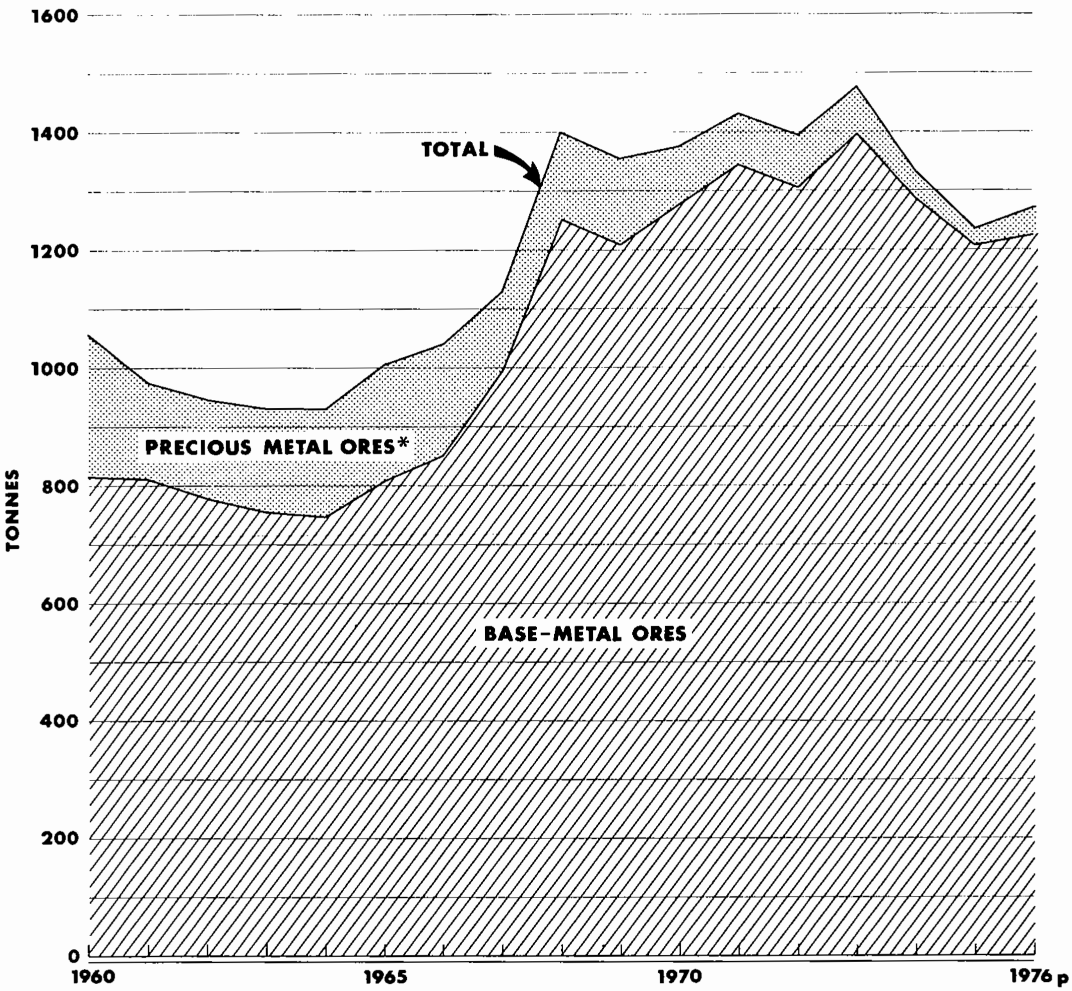
Johnson Matthey & Mallory Limited completed construction of a new $5 million precious metals refinery at Brampton, Ontario. The plant began operations in May 1976. It processes scrap metal, sweeps, polishings, dross and other forms of precious metal scrap material, together with some primary materials such as placer gold and base bullion, primarily for recovery of the contained precious metals. In addition to its newly-installed smelting capacity, the refinery will continue to fire-refine precious metals and upgrade them electrolytically. Rated annual capacity of the new refinery is 62 200 kilograms (2 000 000 ounces) of gold, 155 500 kilograms (5 000 000 ounces) of silver and 1 555 kilograms (50 000 ounces) of the platinum group metals. The company is affiliated with two world-wide organizations; Johnson, Matthey & Co., Limited of London, England; and P.R. Mallory, Inc. of Indianapolis, Indiana, United States.

Based on preliminary figures, Canada was the world's third largest mine producer of silver, being surpassed by the U.S.S.R. and Mexico.

New production of silver in the United States declined somewhat, from 1 085.5 tonnes (34.9 million ounces) in 1975 to 1 057.5 tonnes (34.0 million ounces) in 1976. In the United States, the world's largest silver consumer, consumption for industrial uses and coinage was 5 251.5 tonnes (168.84 million ounces) and 40.9 tonnes (1.31 million ounces), respectively, in 1976. The large deficit in requirements was again met by imports, demonetized coinage, secondary silver derived from discarded jewelry, silverware and films; liquidation of speculative holdings, and withdrawals from industrial and United States Treasury stocks. Most of the requirements for United States coinage were again obtained from Treasury stocks (balance in Bureau of the Mint only) which, in the form of bullion, coin bars and coinage metal fund silver, declined during 1976 from 1 275.6 tonnes (41.0 million ounces) to 1 235.0 tonnes (39.7 million ounces). On October 1, 1976 the United States Federal Preparedness Agency (FPA) announced revised objectives for many materials, including silver, contained in the nation's strategic and critical stockpiles. The new goals are based on three key elements: that the overall stockpile be enlarged from the 1973 proposal for a one-year supply to a level which would sustain a three-year supply in an emergency, that essential civilian requirements be provided for, and that for each year used in planning, stockpile needs be estimated separately for defense and civilian requirements. The new requirements provide for increases or decreases in the objectives for some commodities, while those for other materials remain unchanged. The objective for silver was reduced from 673.8 tonnes (21 663 000 ounces) to zero. The stockpile now contains 4 338.9 tonnes (139 500 000 ounces), all of which is now surplus to the new objective. However, none of this surplus silver may be disposed of without congressional approval, and the disposal policy of the new United States administration has yet to be determined.

In 1976 the United States Mint continued the minting of Eisenhower dollar coins, containing 40 per cent silver, in special sets for numismatists. Production of these commemorative coins began in May 1971 and 150 million were authorized in a provision included in Public Law PL-91-607 which came into effect on December 31, 1970. The use of the metal in these special coins will not have any significant effect on the silver market as the United States Treasury Department, in 1970, had already set aside the silver (about 1 461.9 tonnes or 47 million ounces) that would be required. Part of these requirements resulted from a transfer of 793.1 tonnes (25.5 million ounces) from the strategic stockpile to the United States Mint. The transfer was made in the second quarter of 1971 and

PRIMARY SILVER PRODUCTION in CANADA by SOURCE



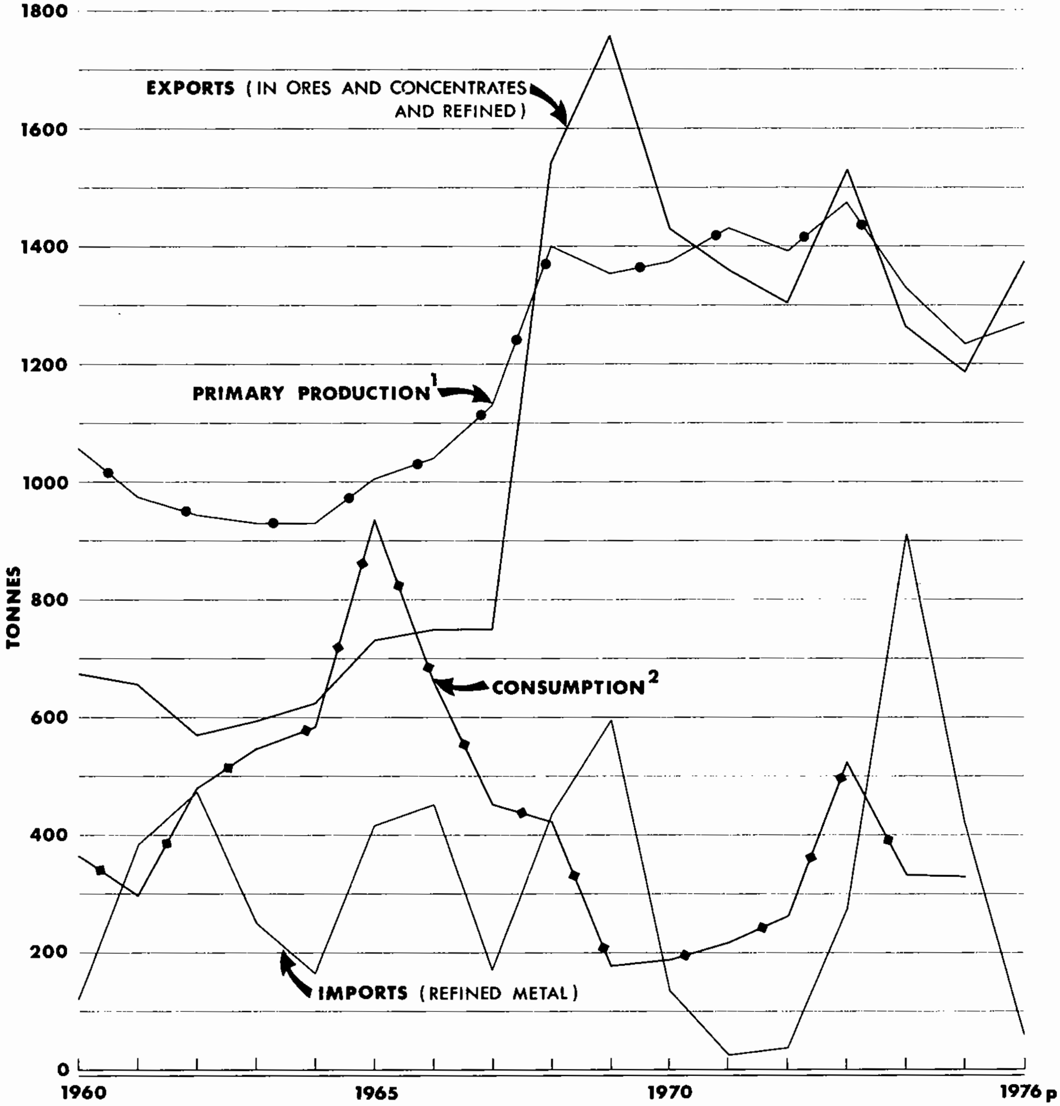
* Mostly from Silver-cobalt ores; some from Gold ores.
p Preliminary

since then the silver inventory in the strategic stockpile has remained at 4 338.9 tonnes (139 500 000 ounces).

Public Law PL-93-127 was enacted October 18, 1973, directing the Secretary of the United States Treasury to mint, prior to July 4, 1975, 45 million silver-clad alloy coins commemorating the Bicentennial of the American Revolution in 1976. The legislation also authorized the minting of not more than an additional 15 million of such coins if there is public demand for them. The coins contain 40 per cent silver and are minted in 25c, 50c and $1.00 denominations. The total of 45 million coins requires 251.0 tonnes (8.07 million ounces) of silver but, if the maximum quantity of 60 million coins are issued, the total amount of silver required will be 334.7 tonnes (10.76 million ounces). The silver for these coins is supplied from current U.S. Treasury stocks.

Mexico and Peru held informal discussions about mid-1974 and again in the early part of 1975 concerning the establishment of the "Association of Silver

SILVER IN CANADA*



* As reported by Statistics Canada
1 As defined in Footnote 1 to Table 1.
2 Statistics for years 1960 to 1973 inclusive include consumption for coinage; 1974 and 1975 statistics include only partial consumption for coinage.
p Preliminary

Exporting Countries" to help maintain "equitable" price levels for the metal in world markets. Mexico and Peru together accounted for about 26 per cent of world mine production of silver in 1976 and are significant exporters. Up to late-1976 no firm action had been taken on the proposed association.

The demonitization of silver-copper coins by the West German government in 1976 resulted in an unexpected increase in world silver supplies from secondary sources. The silver content of the coins, derived mainly from the retired 5-Deutschemark coin which contained 62.5 per cent silver, totalled about 870.9 tonnes (28 million ounces). About half of that quantity of silver was refined in West Germany and the remainder was exported to, and refined in, Switzerland.

Effective August 26, 1976, the Indian government banned exports of silver by private traders. All sales abroad are now being handled by the State Trading Corporation. No reason was given for the decision, but some silver dealers regarded the move as a follow-up to the lifting of the curb on silver exports by the Indian government in February 1974 in an effort to reduce smuggling operations. Early in April 1976 the government announced that, for the fiscal year beginning April 1, 1976, it would limit silver exports to 1 400 tonnes (45 million ounces) a year. Indian exports of silver amounted to about 1 240 tonnes in 1975 and 1 135 tonnes in 1976. the amount of silver held above ground in India is unknown, but is believed to range from 30 000 to 150 000 tonnes. Given sufficient price inducement, India will continue to be an important source of silver.

In the United States the new Coeur mine near Wallace, in northern Idaho, was dedicated early in June 1976. The mine, located a mile up Shields Gulch in the heart of Idaho's historic Silver Belt, began operations in March 1976. About $20 million was invested over the past 12 years in sinking the shaft, underground exploration and development work, and construction and equipping of the 410-tonne-a-day concentrating plant. Capable of producing 68.4 tonnes (2 200 000 ounces) a year of silver contained in concentrates, the Coeur property is the fourth-largest silver mine in the United States. At the end of 1976, assured and probable reserves consisted of 675 000 tonnes of silver-copper ore averaging approximately 754.3 grams of silver a tonne and 0.81 per cent copper. ASARCO Incorporated leases the Coeur mine from Coeur d'Alene Mines Corporation and operates it as a joint venture with Callahan Mining Corporation and Day Mines, Inc.

The DeLamar silver-gold property near DeLamar, Idaho was scheduled to begin operations early in 1977. The property is a joint venture in which Earth Resources Company of Dallas, Texas has a 52½ per cent interest, with the remaining interest held by Superior Oil Company and Canadian Superior Mining Company Limited. The property is managed by Earth Resources under an operating agreement between that company, Superior Oil and Canadian Superior Mining. The mine is an open-pit operation and will require an investment of almost U.S. $20 million to bring it into production. When operating at full capacity the mine is expected to be the third-largest silver mine in the United States. The estimate of the silver content of DeLamar mine's ore reserves was recently doubled from about 775 tonnes to 1 550 tonnes. Average grade of two of the property's mining areas is 144.0 grams of silver a tonne (4.2 ounces per short ton*) and 1.58 grams of gold a tonne (0.046 ounce per short ton). Based on these grades, total reserves are estimated at some 11 000 000 tonnes. Concentrator capacity is 2 180 tonnes of ore a day, but initially the mill will operate at only 1 550 tonnes a day on a 7-day-week basis. Initial output of silver and gold is expected to be equivalent to about 78 tonnes (2.5 million ounces) of silver and 0.7 tonnes (22 000 ounces) of gold a year. At the initial rate of production the mine has a life expectancy of almost 20 years.

The Sunshine Mining Company, operator of the Sunshine Unit Area mine in northern Idaho, resumed operations March 14, 1977 after about 500 striking members of the United Steelworkers of America voted to accept a new 3-year contract offer from the company. The mine is at Kellogg, in the Coeur d'Alene mining district, the major silver-producing belt of the United States, and had been strikebound since March 11, 1976. The property is jointly owned by Sunshine Mining Company (57.14 per cent), Hecla Mining Company (33.25 per cent), and Silver Dollar Mining Company Limited (9.61 per cent). It was expected that the mine would reach full production by about mid-April 1977. In 1975, the last full year of operations, the mine produced 158 600 kilograms (5.1 million ounces) of silver.

ASARCO Incorporated brought into commercial production in 1976 its new $196 million copper refinery at Amarillo, Texas. Included in the Amarillo facility is a precious-metals plant which has a silver refinery with an annual capacity of 1 866.2 tonnes (60 million ounces) of refined silver. The new refinery is one of the world's largest and most modern silver refineries. The operation contains the most sophisticated production, materials handling and environmental equipment and the latest innovations in refinery design.

The El Mochito Mine in the Republic of Honduras, which is 100 per cent owned by Rosario Resources Corporation (a United States company with headquarters in New York City), achieved new record ore production in 1976. The concentrator processed 320 812 tonnes of ore in 1976 from which were derived lead and zinc concentrates and doré bullion, all of which materials contained a total of 99 023.7 kilograms (3 183 686 ounces) of silver. At December 31, 1976 total ore reserves in the El Mochito's orebodies in the

*2 000 pounds avoirdupois.

Main-Yojoa and San Juan areas were reported to be 5 596 400 tonnes with an average grade of 0.31 per cent copper, 4.84 per cent lead, 8.16 per cent zinc, and 176.23 grams of silver and 0.069 gram of gold a tonne.

The Pueblo Viejo open-pit, gold-silver mine in the Province of Sanchez Ramirez in the Dominican Republic completed its first full year of operations at the end of 1976. The property, which is operated by Rosario Dominicana, S.A., is owned 27 per cent by Rosario Resources Corporation (of New York City), 27 per cent by Simplot Industries Inc. (a U.S. corporation) and 46 per cent by the Central Bank of the Dominican Republic. In 1976 the company's 7 250-tonne-a-day concentrator processed 2 622 975 tonnes of gold-silver oxide ore from which was produced doré bullion containing 12 870.271 kilograms (413,789 ounces) of gold and 28 220.758 kilograms (907 318 ounces) of silver. At the end of 1976 oxide ore reserves were reported to be 23 453 454 tonnes grading 4.00 grams of gold and 23.84 grams of silver a tonne. Underlying the oxide ore is a sulphide zone containing geologic reserves estimated at 21 112 242 tonnes averaging 3.57

Table 3. World mine production of silver, 1975-76

	1975[1p]		1976[2p]	
	(troy ounces)	(kilograms)	(troy ounces)	(kilograms)
U.S.S.R.[4]	43 000 000[e]	1 337 500	44 000 000[e]	1 368 600
Mexico	38 029 000	1 182 800	42 600 000	1 325 000
Canada	39 101 000	1 216 200	40 900 000	1 272 100
Peru	37 783 000	1 175 200	39 100 000	1 216 100
United States	34 119 000	1 061 200	34 000 000	1 057 500
Australia	23 537 000	732 100	22 200 000	690 500
Japan	8 649 000	269 000	9 300 000	289 300
Poland	6 500 000[e]	202 200	8 000 000[e]	248 800
Chile	6 263 000	194 800	5 600 000	174 200
Bolivia	5 464 000[3]	170 000	5 200 000	161 700
Sweden	4 300 000[e]	133 800	4 700 000	146 200
Yugoslavia	5 412 000	168 400	4 600 000	143 100
Honduras	3 802 000	118 300	3 200 000	99 500
Republic of South Africa	3 084 000	95 900	2 800 000	87 100
France	1 500 000[e]	46 700	2 700 000	84 100
Spain	3 525 000[4]	109 700	2 200 000	68 400
South Korea	1 504 000	46 800	1 900 000	59 100
Zaire	2 291 000	71 300	1 900 000	59 100
Morocco	3 560 000[e]	110 700	1 800 000	56 000
Argentina	2 000 000[e]	62 200	1 700 000	52 900
North Korea	700 000[e]	21 800	1 600 000[e]	49 800
East Germany (German Democratic Republic)	2 000 000[e]	62 200	1 600 000[e]	49 800
Philippines	1 620 000	50 400	1 500 000	46 700
Romania	1 100 000[e]	34 200	1 300 000[e]	40 400
Czechoslovakia	1 100 000[e]	34 200	1 300 000[e]	40 400
Papua and New Guinea	1 357 000	42 200	1 100 000	34 200
South-West Africa	1 500 000[5]	46 700	1 100 000	34 200
Italy	1 200 000[4e]	37 300	1 100 000	34 200
West Germany	1 200 000[e]	37 300	1 100 000	34 200
Bulgaria	800 000[e]	24 900	1 000 000[e]	31 100
Other countries	7 452 000	231 400	7 830 000	243 500
Total	293 452 000	9 127 400	298 930 000	9 297 800

Sources: For 1975 statistics, United States Department of the Interior, Preprint from the 1975 Bureau of Mines Minerals Yearbook. For 1976 statistics, The Silver Institute of Washington, D.C., U.S.A.
[1]Recoverable content of ores and concentrates produced unless otherwise noted. [2]Figures represent mine production of silver reported on an accountable basis. [3]Includes production by the State mining company, Corporacion Minera de Bolivia (COMIBOL), plus the exports of medium and small (private sector) mines. [4]Smelter and/or refinery production. [5]Data represent recoverable content of Tsumeb Corporation Ltd. concentrates as well as recovery from copper refinery sludges.
[p]Preliminary; [e]Estimated.

grams of gold and 26.1 grams of silver a ton, with 1.40 per cent zinc and 0.143 per cent copper. There is, as yet, no proven method of profitably processing these sulphides at current metal prices.

Mexico, which has some lead-zinc mines that operate primarily for the extraction of silver, increased its mine output of the metal by about 140 000 kilograms (4.5 million ounces) in 1976 and expects a somewhat greater increase in 1977. The Lampazos mine of Mineral Lampazos in the State of Sonora, Mexico; began operations early in 1975 at a rate of some 46 650 kilograms (1.5 million ounces) of silver a year. It marked the beginning of an expansion program under way at several mines in Mexico which could increase the country's mine output of silver to a rate of about 1 700 to 1 860 tonnes (55 to 60 million ounces) by 1980.

Shaft sinking, underground development work and surface plant construction were completed about mid-1976 at four silver-gold mines in Mexico; Las Torres-Cedros (Mother Lode), Peregrina, Cebada and Bolanitos, near the city of Guanajuato about 370 kilometres northwest of Mexico City. The ore produced at the four mines is fed to a centrally located 2 000-tonne-a-day concentrator which began tune-up operations late in February 1976. Initial feed for the concentrator, located on a site adjacent to the Las Torres mine, was provided from about 100 000 tonnes of development ore which had been stockpiled on surface. By the end of 1976 the concentrator had treated 376 905 tonnes of ore yielding 126 575 kilograms (4 069 533 ounces) of silver and 923.7 kilograms (29 699 ounces) of gold. When full production is reached by all four mines, up to 248 800 kilograms (8 000 000 ounces) of silver and 1 555 kilograms (50 000 ounces) of gold could be produced annually. The Las Torres mining complex is now one of the world's largest silver-gold producers. At December 31, 1976, proven and probable ore reserves, after allowing for dilution, at the four operating mines and at the developing Cedros (South) mine totalled 4 165 100 tonnes with an average grade of 342.14 grams of silver and 2.18 grams of gold a tonne. The probability of finding additional ore on the present holdings appears to be good. The company operating the project is Compania Minera Las Torres, S.A., which is owned 30 per cent by Lacana Mining Corporation, 37 per cent by Compania Fresnillo, S.A., and 33 per cent by Industrias Penoles, S.A. Penoles is one of Mexico's largest private mining enterprises. Lacana Mining is a Canadian company with head-quarters in Toronto —formerly Pure Silver Mines Limited. Total capital, including working capital and pre-production interest, invested at the Torres complex to the end of 1976 amounted to $U.S. 43 200 000. A loan of $U.S. 26 300 000 was provided by a consortium of three Canadian banks to Compania Minera Las Torres, S.A. to assit the company in bringing its mines into production. This loan is reportedly the largest ever made to the Mexican private sector by Canadian financial institutions.

In December 1976 the Mexican government announced that it had begun minting new 100-peso silver coins worth about $U.S. 5 each at the then-current exchange rate. It was reported that the issue will consist of 2.5 million pieces, with each coin containing 20 grams of silver for a total content of 50 tonnes of silver. Between 1950 and 1954 Mexico minted a similar silver coin. It is expected that the first issue of the new coins will be released about mid-1977. According to the announcement by the Mexican Treasury Department, the new coin is part of an effort to stem inflation and force Mexicans to save more and buy less. Mexicans are traditional hoarders of silver and gold coins and government economists believe some people will buy the coin rather than dollars. The Mexican peso, which had remained stable at 12.5 to the United States dollar for 22 years, lost almost half its value in relation to the U.S. dollar in less than two months in 1976. It now trades at about 20 pesos to the dollar.

In January 1977 subsidiaries of St. Joe Minerals Corporation and Phelps Dodge Corporation (two United States companies) concluded an agreement with Conzinc Riotinto of Australia, Limited, a subsidiary of Australian Mining & Smelting Ltd., to develop jointly the copper-lead-zinc-silver property at Woodlawn in New South Wales, Australia. Each of the partners has a one-third interest in the project. Government approvals have been received for the project and development of an open-pit mine and construction of a concentrator are expected to be completed by mid-1978. Conzinc Riotinto will provide the first $20.5 million of the total cost of the venture, estimated at approximately U.S. $88 million, with the balance being shared equally by the three coventurers. The deposit contains some 9.1 million tonnes grading 1.8 per cent copper, 3.5 per cent lead, 9.1 per cent zinc and 55.99 grams of silver a tonne.

One of the major projects of M-I-M Holdings Ltd., an Australian company in which ASARCO Incorporated holds a 49 per cent interest, is development of the McArthur River lead-zinc-silver deposit in the Northern Territory of Australia. Development work continued in 1976. A study is also being made to determine the environmental impact of diverting the McArthur River in order to permit development of an open-pit mine. So far, at this sizeable deposit, an orebody has been proven that has an average thickness of 55 metres and contains 190.5 million tonnes of ore grading 9.5 per cent zinc, 4.1 per cent lead and 40.43 grams of silver a tonne. The physical characteristics of the ore, however, are such that only limited success has been achieved so far in devising a practical method of extracting the metals.

Silver prices in 1976 were again characterized by the violent fluctuations that obtained during the previous several years. The volatility was mainly in response to speculative activity which in turn was fostered by economic uncertainties, monetary disturbances and inflationary pressures. The price fluctuations were, however, not as extreme as those in 1974 and 1975. Average prices for 1976 were slightly lower than those for 1975 and no new highs were established. After showing some weakness in January, a generally rising trend prevailed from then until early July. For the next two months prices declined sharply and from October until the end of 1976 they fluctuated in a narrower range, with year-end prices being close to those at the beginning of the year. Dominant factors behind silver price movements in 1976 were a significant increase in industrial consumption (about 8 per cent during the year in the noncommunist world), pronounced speculative activity, a decline in visible stocks, the continuing shortfall between consumption and new production, and silver's use as a hedge against the monetary uncertainties and worldwide inflation that continued in 1976. Other factors influencing the silver price pattern were a relatively low increase in world mine production, the deterring effect of the possible release by the United States government of all, or part of, its strategic stockpile of 4 338.9 tonnes of silver, all of which is surplus to the new (zero) objective, and a tendency for Indian exports to increase appreciably at times of sharp price advances.

On the New York Commodity Exchange, Inc. (Comex), one of the principal futures markets for contracts in silver in the United States, the volume of trading in silver in 1976 amounted to 3 741 908 contracts of 5 000 ounces each, compared with 2 902 315 contracts of 5 000 ounces each in 1975. The volume of silver traded on the Chicago Board of Trade in 1976 amounted to 2 011 043 contracts of 5 000 ounces each, compared with 1 952 693 contracts of the same size traded in 1975. The volume of silver traded on the MidAmerica Commodity Exchange at Chicago in 1976 was 447 513 contracts of 1 000 ounces each, compared with 439 915 contracts of the same size in 1975. Silver traded on the London Metal Exchange was 611 110 000 ounces in 1976, compared with 492 370 000 ounces in 1975.

New York Commodity Exchange, Inc. silver stocks at the end of 1976 were 54.76 million ounces compared with 85.73 million ounces at December 31, 1975. Chicago Board of Trade silver in storage, at the end of 1976 and registered for delivery against futures' contracts, was 61.04 million ounces, compared with 38.47 million ounces at December 31, 1975. Both figures for the Chicago Exchange are exclusive of some additional silver that may have been in stocks at such times, but not registered for future delivery. London Metal

Table 4. Noncommunist world consumption of silver, 1975-76

	1975		1976^p	
	(troy ounces)	(kilograms)	(troy ounces)	(kilograms)
Industrial uses				
United States	157 700 000	4 905 000	167 500 000	5 209 800
Japan	46 400 000	1 443 200	56 000 000	1 741 800
West Germany	44 000 000	1 368 600	42 000 000	1 306 300
United Kingdom	27 500 000	855 300	28 000 000	870 900
Italy	26 000 000	808 700	28 000 000	870 900
France	18 000 000	559 900	19 000 000	591 000
India	13 000 000	404 300	18 000 000	559 900
Mexico	6 000 000	186 600	7 000 000	217 700
Canada	7 700 000	239 500	6 500 000	202 200
Other countries	19 000 000	591 000	23 000 000	715 400
Total industrial uses	365 300 000	11 362 100	395 000 000	12 285 900
Coinage				
Canada	10 000 000	311 000	6 000 000	186 600
France	3 000 000	93 300	5 800 000	180 400
Austria	5 000 000	155 500	5 500 000	171 100
West Germany	5 500 000	171 100	1 800 000	56 000
United States	2 700 000	84 000	1 300 000	40 400
Other countries	3 000 000	93 300	6 600 000	205 300
Total coinage	29 200 000	908 200	27 000 000	839 800
Total consumption	394 500 000	12 270 300	422 000 000	13 125 700

Source: Handy & Harman, *The Silver Market 1976.*
^p Preliminary.

Exchange stocks at the end of 1976 were 28.50 million ounces, compared with 17.83 million ounces at the end of 1975. United States industrial stocks* on December 31, 1976 were reported to be some 30.63 million ounces, compared with about 34.62 million ounces at the end of 1975.

Outlook

Canada's primary production** of silver in 1977 is forecast to be 1 350 tonnes and is expected to range between 1 250 and 1 450 tonnes annually from 1978 to 1982.

World demand for silver increased in 1976, mainly as a result of the improved economic activity in the major industrialized nations. However, with the world's economy now faltering in its efforts to recover from the 1974-75 recession, a small increase, or possibly a slight decrease, in silver consumption is expected in 1977. However, the long-term demand for silver for industrial uses is expected to increase significantly.

Consumption will, nevertheless, continue to exceed primary production by a wide margin as mine output of silver is largely related to the production of the major base-metal ores. About 80 per cent (almost 85 per cent in Canada) of the world's mine output of silver is derived as a byproduct or coproduct in the mining of such ores and, accordingly, the supply of newly-mined silver continues to depend more on the production of base-metal ores than on the demand for or price of silver. Over the next few years a significant increase in mine output of silver is expected in Mexico where a substantial portion of that country's silver production is derived from mines whose primary product is silver.

Because of large world stocks and a sluggish demand for the major base-metals, cutbacks in production of these metals, initiated in 1974, continued through 1976 and are still persisting in some countries in 1977. These cutbacks resulted in reduced mine output of silver from such sources. In the short-term, however, there should be no real shortage of silver for industrial requirements. Sufficient quantities of secondary silver, speculative holdings, greater Indian exports and some hoarded silver coins will continue to find their way into the market. Because of better prices and the increasing emphasis being placed on recycling by both government and industry, greater quantities of secondary silver are reaching the market. One significantly increasing source of secondary silver results from microfilms being used to record data from the much-larger X-ray negatives, thus making possible the immediate recycling of the silver used in the original films.

Among the "bullish" factors influencing the silver market are the big perennial, and now increasing, deficiency between new production and consumption, a projected increase in industrial demand should the western economies pick up steam, and a slight drop in world stocks of silver that occurred in 1976. "Bearish" elements include the 4 338.9 tonnes of surplus silver in the United States government's strategic stockpile and the possibility of increasing exports from India. Depressing factors, insofar as mine output of silver is concerned, are the lower base-metal prices, high inflation, rising operating costs and — according to the industry — the onerous mineral taxes that are plaguing the metal mining industry. As a result of this adverse economic climate, several base-metal mines have reduced output and others plan to do so. Exploration and development work have also been curtailed. Such measures do not augur well for the future supply of silver. The profitability, as well as the ability of the metal mining industry to explore for and develop new or alternative sources of raw materials' has been impaired; and, even worse, the industry's ability to replace existing facilities and ore reserves is being severely restricted.

It is expected that silver prices will be erratic again in 1977, although displaying a somewhat upward trend. Again, the price fluctuations will not be entirely governed by the law of supply and demand but will continue to be affected by the whims and actions of the speculators. An ill omen is that the economic recovery in most industrialized countries is continuing at only a sluggish pace and world-wide inflation has not been brought under control. Excepting the Middle East, the world economy is still struggling to absorb the higher energy costs. In spite of these adverse economic conditions, the outlook for silver is bright. Because of inflation and the depreciating power of paper currencies, the speculative demand for silver could increase. In 1977, the silver price could range between $U.S. 4.25 and 5.25 an ounce, but the price trend for the next few years should be upward. However, increased exports from India as well as greater supplies from secondary sources could act as a brake to any sharp silver price rise.

Canadian developments

Atlantic Provinces. Silver production in the Atlantic provinces was lower in 1976 than in the previous year, mainly because of lower byproduct output by Brunswick Mining and Smelting Corporation Limited which had a 3-month labour strike at its silver-base-metals property near Bathurst, New Brunswick.

Effective January 1, 1976, a new 25-year, co-tenancy agreement was entered into by ASARCO Incorporated and The Price Company Limited covering their joint venture in the zinc-lead-copper-silver mine at Buchans, Newfoundland. The Price Company controls the underlying rights. However, under the new arrangement, ASARCO retains a 49 per cent interest in the property and will continue to manage the mining and milling operations. The Buchan's mine has ore reserves sufficient to support mining operations

*Refiner, fabricator and dealer stocks.

**As defined in the footnote to Table 1.

for about four years at the current rate of production.

At its silver-base-metals property near Bathurst, New Brunswick, Brunswick Mining and Smelting Corporation Limited continued its program to expand production from its No. 12 mine to 10 000 tonnes of ore a day in 1979, compared with the present maximum hoisting capability of 6 350 tonnes a day. Cost escalations, however, have raised the estimated cost of the project (before addition of capitalized interest) from $48.1 to $53 million, of which about $33.6 million had been spent to the end of June 1977. The project includes sinking of the new No. 3, 8-metre-diameter shaft to a depth of 1 310 metres from surface and at the end of July 1977 this new shaft had reached a depth of 975 metres below surface. Stope development began early in 1976 at Brunswick's No. 6 underground mine after a decline was driven below the No. 6 open-pit mine, at which operations will be phased out in 1977.

At the Little River silver-base-metals property of Heath Steele Mines Limited near Newcastle, N.B., work was completed on an expansion program which included sinking the new No. 5 shaft to a depth of 990 metres. Ore production at the increased rate of 3 630 tonnes a day began near the end of 1976.

Nigadoo River Mines Limited completed, in 1976, its second full year of operations since resuming production early in January 1974 at its zinc-lead-copper-silver property near Bathurst. However, because of higher operating costs and declining base-metal prices, ore reserves are declining and it now appears that operations could be suspended within the next few months. At September 1, 1976, ore reserves were estimated at 289 200 tonnes grading 0.16 per cent copper, 3.24 per cent lead, 2.92 per cent zinc and 117.94 grams of silver a tonne.

The mining and exploration sectors in New Brunswick continued, in 1976, to be amongst the most buoyant of any in the Canadian provinces, partly because New Brunswick's mineral taxation policies have been such as to encourage the maximum amount of exploration, development and processing by the private sector of the mining industry.

Quebec. Silver production in Quebec, derived mostly from base-metal ores, was somewhat higher in 1976 than in 1975, partly because of significant byproduct output derived from the zinc-copper-silver-gold property near Chibougamau of Lemoine Mines Limited, which began operations early in 1976. Lemoine Mines is a wholly-owned subsidiary of Patino Mines (Quebec) Limited; the latter's parent company is Patino, N.V. of the Netherlands. When operations began at Lemoine's 360-tonne-a-day concentrator, the property's ore reserves were, after allowing for 15 per cent dilution, estimated at 567 000 tonnes grading 10.8 per cent zinc, 4.5 per cent copper, and 92.57 grams of silver and 4.73 grams of gold a tonne. Also contributing to the increased silver output in Quebec was that derived from the Norita Division's zinc-copper-silver property. The Norita mine is operated and controlled by Orchan Mines Limited and is about 13 kilometres northeast of the main Orchan mine in the Matagami Lake area of northwestern Quebec. Production at a rate of 815 tonnes of ore a day began in May 1976, with the ore being processed at the nearby Orchan concentrator.

Silver output in Quebec in 1977 will be adversely affected by the decision announced late in 1976 by the Sullivan Mining Group Ltd. to close on January 31, 1977, its Cupra and D'Estrie silver-base-metal mines in the Eastern Townships because of depressed copper prices and operating difficulties. Madeleine Mines Ltd. also announced late in 1976 that it would gradually suspend operations for an indefinite period at its copper-silver mine near Ste-Anne-des-Monts because of a decline in the grade of ore, depleted reserves, higher operating costs, and the unfavourable outlook for copper prices in the near-term. Operations were finally terminated December 31, 1976, but a mine crew remains on the property to maintain the mine and plant on a standby basis with a view to reactivating it at such time as there is sufficient improvement in copper prices to warrant profitable operation.

Early in 1976 Orchan Mines Limited, Noranda Mines Limited and Manitou-Barvue Mines Limited finalized a joint-venture agreement to bring back into production Manitou Barvue's zinc-silver property in Barraute township in northwestern Quebec. It was expected that the property would be brought into production as soon as market conditions warrant and funds become available. When production ceased at the property in 1957 the mineralized deposit contained 3.6 million tonnes grading 3.5 per cent zinc and 41.14 grams of silver a tonne to the 183-metre level.

About mid-1976 crews were at work on the "Detour Project" of Selco Mining Corporation Limited (in which Selection Trust Limited of London, England has a 94 per cent interest) and Pickands Mather & Co. of Cleveland, Ohio, clearing the site for a shaft soon to be put down on the B zone. Selco and Pickands Mather are equal partners in the property, although it is managed by Selco. Work to date on this major copper-zinc-silver-gold property in the Brouillan township area of northwestern Quebec has revealed three zones of interest, designated the A-1, A-2 and B zones. A preliminary estimate based on the results of diamond drilling from the A-1 zone has indicated the presence of a near-surface deposit of 32.1 million tonnes with an average diluted grade of 0.39 per cent copper, 2.30 per cent zinc, 35.7 grams of silver and 0.31 gram of gold a tonne. The $13 million underground development program which the company announced early in 1976 will permit underground exploration of the A-1 and B zones, and is scheduled for completion by June 1978. The joint venture also purchased the 1 800-tonne-a-day concentrator and surface plant of Mines de Poirier at nearby Joutel.

In August 1976, Manitou-Barvue Mines Limited accepted an offer of $3.1 million from Louvem Mining Company Inc., a wholly owned subsidiary of Quebec

(text continued on page 500)

Table 5. Principal silver (mine) producers in Canada, 1976 and (1975)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
Newfoundland								
ASARCO Incorporated, Buchans (formerly listed as American Smelting and Refining Company)	1 150 (1 150)	105.60 (103.88)	0.96 (0.95)	6.03 (5.92)	10.69 (10.54)	188 694 (210 467)	17 216.7 (18 999.9)	ASARCO has a new agreement with The Price Co. Ltd. whereby it retains 49% interest in property and continues to manage operations.
Consolidated Rambler Mines Limited, Baie Verte	1 100 (1 100)	21.74 (19.54)	3.68 (3.20)	— (—)	— (—)	187 284 (203 719)	3 461.1 (3 374.5)	Continuing normal exploration program.
New Brunswick								
Brunswick Mining and Smelting Corporation Limited, Nos. 12 and 6 mines, Bathurst[1]	8 950 (9 100)	86.32 (79.88)	0.38 (0.40)	2.87 (2.95)	7.18 (7.11)	2 247 211 (3 109 139)	113 550.6[e] (167 523.3)[e]	Operations curtailed in 1976 by a 3-month strike at the mine.
Heath Steele Mines Limited, Newcastle	3 650 (2 800)	77.83 (59.31)	0.99 (1.03)	1.85 (1.54)	4.53 (3.99)	1 052 567 (988 326)	49 746.7 (31 938.4)	Completed mining remnants of A-mine orebody.
Nigadoo River Mines Limited, Bathurst	1 050 (900)	93.94 (117.94)	0.157 (0.25)	2.43 (2.55)	2.63 (2.69)	198 698 (231 403)	15 100.0[e] (19 669.7)[e]	Ore reserves at September 1, 1976 were 289 236 tonnes averaging 0.16% copper, 3.24% lead, 2.92% zinc and 117.94 grams of silver a tonne.
Quebec								
Campbell Chibougamau Mines Ltd., Cedar Bay and Henderson mines, Chibougamau	3 650 (3 650)	8.64 (7.85)	1.62 (1.31)	— (—)	— (—)	132 996 (199 166)	652.0 (695.4)	New 2-year labour agreement signed August 31, 1976.
Clinton Copper Mines Ltd., Notre Dame des Bois	ore custom-milled	— (30.03)	— (2.59)	— (0.47)	— (2.49)	— (66 710)	— (1 547.7)	Mining operations terminated in June 1975.

Falconbridge Copper Limited, Lake Dufault Division, Millenbach and Norbec mines, Noranda	1 400 (1 400)	41.49 (34.84)	3.09 (2.50)	— (—)	3.44 (3.35)	458 447 (508 727)	15 396.2[e] (14 232.4)[e]	Norbec mine closed permanently.
Falconbridge Copper Limited, Opemiska Division, Perry and Springer mines, Chapais	2 900 (2 700)	12.55 (11.31)	2.01 (2.02)	— (—)	— (—)	947 053 (863 640)	9 786.7 (8 242.4)	Development of Cooke mine continuing, with production expected to begin in third quarter 1977.
Gaspe Copper Mines, Limited, Needle Mountain and Copper Mountain mines, Murdochville	30 400 (30 600)	. . (4.11)	0.53 (0.52)	— (—)	— (—)	11 139 321 (9 972 777)	22 730.5 (24 841.9)	Work force reduced by 10% in 1976.
La Societe miniere Louvem inc., Louvicourt	. . (. .)	56.23 (. .)	. . (. .)	. . (. .)	5.99 (. .)	258 534 (136 502)	12 447.6[e] (4 204.4)[e]	
Lemoine Mines Limited, Chibougamau	350 (—)	96.68 (—)	4.35 (—)	— (—)	0.40 (—)	88 237 (—)	7 295.0 (—)	Concentrator began tune-up operations early 1976.
Madeleine Mines Ltd., Ste-Anne-Des-Monts	2 250 (2 250)	. . (6.86)	1.007 (1.148)	— (—)	— (—)	738 398 (823 928)	4 576.4 (5 443.0)	Late in 1976 company suspended operations for an indefinite period.
Manitou-Barvue Mines Limited, Golden Manitou mine,[2] Val d'Or	1 450 (1 450)	. . (84.34)	. . (. .)	. . (0.30)	. . (1.81)	. . (222 219)	. . (9 551.8)	Company's mine and mill sold Aug. 11, 1976 to Louvem Mining Company Inc., a wholly owned subsidiary of Quebec Mining Exploration Company (SOQUEM) a Quebec government agency.
Mattagami Lake Mines Limited, Matagami	3 500 (3 500)	31.89 (29.48)	0.55 (0.62)	0.10 (. .)	7.3 (7.3)	1 112 156 (1 166 370)	16 010.7 (14 662.2)	Began exploration decline from 265-metre level to 610-metre level.
Noranda Mines Limited, Horne Division, Horne Mine, Noranda	1 900 (1 900)	. . (. .)	. . (. .)	— (—)	— (—)	123 745[3] 256 061[3]	992.5 (3 246.4)	Horne mine suspended operations July 1, 1976.
Orchan Mines Limited, Matagami	1 700 (1 700)	31.89 (16.46)	0.78 (1.19)	— (—)	6.74 (4.65)	424 259 (382 655)	6 685.6[e] (3 017.0)[e]	Norita Division came into full production last quarter of 1976.
Patino Mines (Quebec) Limited, Chibougamau	2 550 (1 550)	10.29 (8.50)	1.72 (1.67)	— (—)	— (—)	516 356 (398 721)	3 581.9 (2 402.7)	

Table 5. (cont'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
Quebec (cont'd)								
Sullivan Mining Group Ltd., Stratford Centre	1 250 (1 250)							
Cupra Division		. . (33.33)	. . (2.24)	. . (0.47)	. . (4.12)	. . (50 855)	. . (1 494.3)[e]	Operations suspended January 31, 1977.
D'Estrie Mining Company Ltd.		. . (38.26)	. . (2.57)	. . (0.54)	. . (2.12)	. . (163 379)	. . (5 186.8)[e]	Operations suspended January 31, 1977.
Ontario								
Agnico-Eagle Mines Limited, Cobalt district	350 (350)	200.23 (639.42)	. . (. .)	— (—)	— (—)	37 607 (15 794)	5 999.4 (9 558.5)	Exploration continuing at Temiskaming property.
Canadaka Mines Limited, Cobalt district	500 (150)	— (. .)	— (. .)	— (—)	— (—)	— (9 906)	— (2 018.9)	Building new concentrator to replace that destroyed by fire in May 1975.
Falconbridge Copper Limited, Sturgeon Lake Joint Venture, Sturgeon Lake	1 100 (1 100)	183.77 (182.06)	2.15 (2.78)	1.23 (1.17)	9.57 (9.07)	377 256 (341 720)	36 448.4[e] (34 120.3)[e]	Plans further exploration work in 1977.
Falconbridge Nickel Mines Limited, Ontario mines, Sudbury district	12 700 (11 150)	. . (. .)	. . (. .)	— (—)	— (—)	2 920 552 (2 732 445)	. . (. .)	The East, Onaping, Fecunis and Longvack South mines were closed in 1975 and remained idle in 1976. Ore reserves at Sudbury operations at end of 1976 were 75 664 000 tonnes grading 1.46% nickel and 0.68% copper.
Inco Limited, Sudbury and Shebandowan, Ont., and Thompson, Man.	77 950 (77 950)	. . (. .)	0.97 (0.92)	— (—)	— (—)	17 962 258 (19 232 316)	37 013.1[4] (59 096.6)[4]	Ore produced in 1976 also graded 1.41 per cent nickel.

Mattabi Mines Limited, Sturgeon Lake	2 700 (2 700)	121.03 (110.74)	1.23 (0.97)	0.76 (0.70)	8.13 (7.34)	966 797 (975 154)	82 245.2[e] (70 024.3)[e]	
Noranda Mines Limited, Geco Division, Manitouwadge	4 550 (4 550)	44.23 (49.37)	1.69 (1.84)	0.12 (. .)	2.55 (3.54)	1 529 780 (1 450 890)	52 826.7 (56 343.3)	Production limited in 1976 due to lower metal market requirements.
Selco Mining Corporation Limited, South Bay Division, Uchi Lake area	450 (450)	79.88 (93.60)	1.73 (1.82)	. . (. .)	10.38 (11.18)	163 482 (152 701)	10 036.2[e] (12 194.6)	Deepening shaft by 92 metres.
Teck Corporation Limited, Silverfields Division, Cobalt district	250 (250)	246.85 (332.57)	0.5 (0.4)	— (—)	— (—)	69 989 (43 918)	17 388.1 (14 651.3)	Operations suspended July 12, 1975 to mid-February 1976 by a strike.
Texasgulf Canada Ltd., Kidd Creek mine, Timmins[5]	9 050 (9 050)	119.71 (106.28)	1.74 (1.71)	. . (0.25)	8.05 (8.20)	3 242 278 (3 293 284)	323 942.7 (282 315.2)	Mine and concentrator expansion from 3.27 million to 4.54 million tonnes of ore a year to be completed by 1979.
Union Miniere Explorations and Mining Corporation Limited, Thierry mine, Pickle Lake area	3 650 (—)	7.54 (—)	1.14 (—)	— (—)	— (—)	230 608 (—)	1 177.6 (—)	Concentrator began tune-up operations in August 1976.
Willroy Mines Limited, Willroy and Willecho mines, Manitouwadge	1 450 (1 250)	54.51 (53.49)	0.56 (0.42)	0.17 (0.22)	3.67 (3.82)	311 430 (296 970)	11 948.7 (10 764.7)	Operations suspended March 17, 1977.
Manitoba-Saskatchewan								
Hudson Bay Mining and Smelting Co., Limited, Flin Flon and Snow Lake districts	7 700 (7 700)	20.57 (20.57)	2.3 (2.4)	0.2 (0.2)	2.7 (3.0)	1 417 617 (1 333 704)	21 679.4 (20 134.2)	Schist Lake mine ceased operations in third quarter of 1976.
Inco Limited, Thompson, Man.		(included with this company's listing for Ontario)						
Sherritt Gordon Mines Limited, Fox mine, Lynn Lake	. . (2 600)	. . (. .)	1.560 (1.735)	— (—)	1.681 (1.814)	755 122 (913 701)	6 325.5[e] (7 243.9)	Developing underground below the 610-metre level.
Ruttan mine, Ruttan	. . (9 050)	. . (. .)	1.083 (0.96)	— (—)	2.143 (1.90)	2 413 867 (3 030 717)	16 321.5[e] (10 518.5)	Continued underground development work.

Table 5. (cont'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
British Columbia								
Bethlehem Copper Corporation, Highland Valley	18 150 (18 150)	. . (0.62)	0.444 (0.474)	— (—)	— (—)	6 763 873 (5 864 531)	4 942.3 (4 724.6)	Substantial stripping program required in 1977 to prepare Jersey Mine to supply ore in 1978 when Iona deposit is exhausted.
Brenda Mines Ltd., Peachland	21 750 (21 750)	. . (. .)	0.167 (0.188)	— (—)	— (—)	10 047 615 (9 115 887)	7 891.5 (7 872.6)	Modest exploration program for additional ore will be undertaken in 1977.
Cominco Ltd., Sullivan mine, Kimberley	9 050 (7 250)	45.94 (43.54)	. . (. .)	4.0 (3.85)	3.95 (4.16)	2 124 892 (2 002 926)	84 701.3 (73 125.3)	Mining system being modernized to improve productivity.
Dankoe Mines Ltd., Keremeos	150 (400)	. . (40.43)	. . (. .)	. . (4.0)	. . (2.0)	. . (17 914)	7 896.0[e] (10 116.9)	Custom-milled Dusty Mac ore until June 14, 1976; then milled own ore until year-end.
Dusty Mac Mines Ltd., Keremeos	ore custom-milled	146.40 (145.03)	. . (. .)	. . (. .)	. . (—)	53 517 (39 940)	5 824.8 (4 293.3)	Ore custom-milled by Dankoe Mines Ltd.
Gibraltar Mines Ltd., McLeese Lake, Cariboo district	36 300 (36 300)	. . (. .)	0.45 (0.431)	— (—)	— (—)	7 672 336 (10 387 265)	. . (. .)	In 1976 began development of Pollyana pit.
Granby Mining Corporation, Phoenix Copper Division, Greenwood	2 600 (2 550)	6.17 (6.00)	0.50 (0.487)	— (—)	— (—)	965 850 (985 880)	3 261.4 (3 654.7)	Mining operations ceased in August 1976.
Newmont Mines Limited, Stewart	6 800 (6 800)	. . (. .)	1.26 (1.20)	— (—)	— (—)	1 315 912 (1 499 576)	10 649.2 (10 583.8)	By June 1, 1976 ore production reduced from 4 080 to 3 085 tonnes a day.
Granisle Copper Limited, Granisle mine, Babine Lake	12 700 (11 800)	2.06 (1.30)	0.42 (0.436)	— (—)	— (—)	4 008 242 (4 475 126)	4 880.9 (5 610.8)	As at September 30, 1976 ore reserves estimated at 53 250 000 tonnes averaging 0.42% copper.

Kam-Kotia Mines Limited, Silmonac mine, Slocan district	100 (100)	457.71 (599.31)	. . (. .)	5.3 (5.66)	4.86 (4.82)	16 694 (10 927)	7 408.8 (6 229.0)	Operations to continue on a salvage basis.
Lornex Mining Corporation Ltd., Highland Valley	34 450 (40 800)	. . (. .)	0.511 (0.495)	— (—)	— (—)	15 436 973 (11 696 475)	15 585.3 (11 702.0)	Ore reserves at December 31, 1976 were estimated at 453.6 million tonnes averaging 0.412% copper and 0.015% molybdenum.
Northair Mines Ltd., Alta Lake	250 (—)	111.77[e] (—)	. . (—)	0.86[e] (—)	1.81[e] (—)	47 553 (—)	3 662.4 (—)	Mill tune-up operations began in May 1976. Ore also contains about 15.8 grams of gold a tonne.
Reeves MacDonald Mines Limited, Annex mine, Remac	— (900)	— (20.57)	— (. .)	— (0.58)	— (3.07)	— (32 211)	— (296.9)	Mine ceased operations end of first quarter 1975.
Similkameen Mining Company Limited, Ingerbelle Pit, Princeton	19 150 (13 600)	. . (0.73)	0.42 (0.46)	— (—)	— (—)	6 355 736 (3 694 056)	4 578.4 (2 687.6)	In March 1976 completed expansion of mill capacity from 13 610 to 19 960 tonnes a day.
Teck Corporation Limited, Beaverdell mine, Beaverdell	100 (100)	336.34 (318.85)	. . (. .)	0.43 (0.38)	0.54 (0.39)	34 448 (34 898)	11 583.6 (11 131.3)	Operations to continue on a salvage basis.
Utah Mines Ltd., Island Copper mine, Coal Harbour, Vancouver Island	34 450 (34 450)	. . (. .)	0.47 (0.48)	— (—)	— (—)	12 246 994 (12 056 557)	9 642.1 (9 517.7)	
Wesfrob Mines Limited, Tasu Harbour, Queen Charlotte Islands	4 650 (5 250)	. . (. .)	. . (0.212)	— (—)	— (—)	. . (1 622 394)	2 870.5 (1 739.5)	Open pits to be exhausted in mid-1977, after which all production will be from underground.
Western Mines Limited, Buttle Lake, Vancouver Island	700 (1 000)	169.37 (153.94)	1.19 (1.12)	1.42 (1.42)	7.73 (7.59)	269 294 (260 719)	41 972.6[e] (36 908.3)[e]	A new ore zone, the "S" zone, discovered in 1976 at the Lynx mine.
Yukon Territory								
Cyprus Anvil Mining Corporation, Faro	9 050 (9 050)	16.46 (. .)	. . (. .)	2.66 (4.03)	5.48 (5.41)	1 519 880 (2 925 873)	21 264.5[e] (93 661.1)[e]	Production curtailed in 1976 because of three labour strikes.
United Keno Hill Mines Limited, Husky, Keno, Elsa, No Cash, Dixie mines, Elsa	200 (450)	1 216.79 (1 198.62)	. . (. .)	4.02 (4.03)	1.17 (1.15)	68 506 (82 427)	74 305.9[e] (93 644.8)[e]	Plans to continue extensive exploration work.
Whitehorse Copper Mines Ltd., Whitehorse	2 250 (2 200)	. . (. .)	1.69 (1.52)	— (—)	— (—)	726 506 (669 559)	7 500.9 (6 761.9)	Installed underground crusher and conveyor.

Table 5. (concl'd)

Company and Location	Mill or Mine Capacity	Grade of Ore Milled: Silver	Copper	Lead	Zinc	Ore Milled	Silver Contained in Concentrates Produced	Remarks
	(tonnes of ore/day)	(grams/ tonne)	(%)	(%)	(%)	(tonnes)	(kilograms)	
Northwest Territories								
Echo Bay Mines Ltd., Port Radium	100 (150)	. . (. .)	. . (. .)	. . (. .)	. . (. .)	35 731 (28 350)	57 759.2 (23 991.1)	Completed Echo Bay mine. All ore supplied to mill is now from Eldorado mine.
Nanisivik Mines Ltd. Strathcona Sound, Baffin Island	1 350 (—)	. . (—)	. . (—)	2.9 (—)	14.5 (—)	70 760 (—)	. . (—)	Mill tune-up operations began September 1976.
Terra Mining and Exploration Limited, Camsell River area	200 (150)	1 491.41 (. .)	. . (. .)	. . (. .)	. . (. .)	41 812 (38 901)	59 127.6 (41 079.1)	Plans to increase capacity of mine and mill to 81 647 tonnes of ore a year.

Sources: Company reports and technical press.
[1]All statistical data, including mill capacity, represent combined results for Nos. 12 and 6 mines and mills. [2]Grade and production statistics for 1975 do not include a total of 154 958 tons of combined copper and zinc ores custom-milled in separate circuits. [3] Figures are exclusive of 382 220 and 294 455 tonnes of silver-containing copper slags processed in the Horne concentrator in 1976 and 1975, respectively. [4]Silver delivered to markets. [5]Figures represent combined averages and totals of A and C ores processed.
[e] Estimated; — Nil; . . Not available.

Table 6. Prospective[1] silver producing mines in Canada

Company and Location	Year Production Expected	Planned Mill or Mine Capacity	Reported Ore Reserves	Average Grade of Ore: Silver	Copper	Lead	Zinc	Remarks
		(tonnes ore/day)	(tonnes)	(grams/ tonne)	(%)	(%)	(%)	
Quebec								
Falconbridge Copper Limited, Opemiska Division, Cooke mine, Chapais	1977	270	503 500	. .	1.46	–	. .	
Macdonald Mines, Ltd., Noranda area	. .	. .	1 995 800	30.86	0.1	—	5.6	This property is controlled by Noranda Mines Limited.

Noranda Mines Limited and Orchan Mines Limited, Barvue zinc-silver property, Barraute township	. .	. .	3 629 000	37.32	. .	. .	3.5	Production to begin as soon as market conditions warrant.
Noranda Mines Limited, New Insco property, Noranda area	. .	. .	736 000	31.10	2.8	. .	—	Ore also contains 0.622 grams of gold a tonne.
Orchan Mines Limited, P.D. Division, La Gauchetiere township, Matagami area	1978	725	1 401 600	17.14	0.9	—	4.5	Excavations being made at mine site for an adit decline to develop upper part of ore zone and establish collar for vertical shaft.
Ontario								
Mattagami Lake Mines Limited, Lyon Lake orebodies, Sturgeon Lake	1977	910	3 656 000	116.23	1.15	0.63	6.66	Shaft sinking is complete and installation of services is in progress.
Texasgulf Canada Ltd. No. 2 mine, Timmins	1978	. .	. .	. .	. .	. .	. .	At March 31, 1977, the shaft for the No. 2 mine, which will be 1 554 metres deep, had reached a depth of 1 433 metres.
Manitoba-Saskatchewan								
Hudson Bay Mining and Smelting Co., Limited, Flin Flon district								
Westarm mine	1977	. .	644 100	. .	4.63	. .	0.6	Shaft completed to depth of 580 metres below surface.

[1]Those mines which have announced production plans.
— Nil; . . Not available.

Mining Exploration Company (SOQUEM), to purchase its Golden Manitou mine, mill and plant and operating supplies located in Bourlamaque township. This silver-base metals mine has for a good many years been a significant producer of byproduct silver. On December 31, 1975 total silver-zinc ore reserves, after an allowance for dilution, were estimated at 826 000 tonnes grading 2.32 per cent zinc, 0.39 per cent lead, 136.5 grams of silver and 0.75 gram of gold a tonne.

Ontario. Ontario was again, by far, the leading silver-producing province or territory, with its output in 1976 accounting for more than 38 per cent of Canadian production. The leading producer was Texasgulf Canada Ltd., which recovered over 323 900 kilograms (10.4 million ounces) in copper, lead and zinc concentrates at its Kidd Creek property, the largest single mine producer of silver in Canada, and probably the world.

In a 50-50 joint venture with the Canadian subsidiary of Pechiney Ugine Kuhlmann Development, Inc., of Paris, France, St. Joseph Explorations Limited, a wholly-owned subsidiary of St. Joe Minerals Corporation of New York, completed construction of a silver treatment plant and refinery at Cobalt, Ontario. The operating company is known as Canadian Smelting and Refining (1974) Limited. The new plant began tune-up operations early in 1976 and reached the commercial production stage a few months later. The plant, designed especially to treat the arsenic-rich ores and concentrates produced by the Cobalt area mines, is a hydrometallurgical operation using an acid-wash cyanidation process. It is expected to be able to process any silver-cobalt ores and concentrates produced in the Cobalt area, including lower-grade flotation concentrates. The plant also expects to treat similar-type concentrates, or silver-containing precipitates, residues or secondary materials, produced elsewhere. The major product is refined silver, with the annual capacity being up to 187 000 kilograms (6 million ounces) of silver, depending on the nature of the materials processed. Grade of the refined silver is 99.95+ per cent silver. Among the byproducts expected to be produced are precipitates, residues or other materials containing cobalt, nickel, copper, lead and antimony. The new plant gives the Cobalt area silver producers the renewed opportunity of having their ores and concentrates processed locally. Since the Refinery Division of Kam-Kotia Mines Limited suspended operations in February 1972 at its silver refinery at Cobalt, the mine producers in the area have had to ship their products to other Canadian or foreign plants for treatment.

Late in January 1977, tune-up operations began at the new concentrator at the Cobalt area property of Canadaka Mines Limited, a wholly owned subsidiary of St. Joseph Explorations Limited. The concentrator, which replaces the former one destroyed by fire in May 1975, reached full operating capacity of 500 tonnes of ore a day in April 1977. It is the largest, most modern and most automated mill ever built in the Cobalt-Gowganda area. It is currently processing newly mined ore, old mill tailings and material from old mine dumps.

At the Kidd Creek property of Texasgulf Canada Ltd. near Timmins, Ontario, work continued on schedule on the $300-$350 million (original estimate) expansion program begun in 1974. Included in the program is a transition from open-pit to underground mining, with mine production being increased from 3.3 to 4.5 million tonnes of ore a year, installation of a fourth 3 175-tonne-a-day circuit in the concentrator, and construction of a 118 000-tonne-a-year copper smelter and refinery complex at the Kidd Creek metallurgical site. Development of the No. 2 underground mine is on schedule, with the 1 555-metre shaft for the No. 2 mine having been sunk to a depth of 1 430 metres by the end of March, 1977. Mining of the open-pit was scheduled for completion by the end of 1976. Start-up of the fourth 3 175-tonne-a-day circuit in the concentrator is scheduled for late 1978. Included in the new refinery complex is a silver refinery. Construction of the copper smelter and refinery began in the spring of 1976 and completion of the first 59 000-tonne unit, although scheduled for late 1978, could be modified in view of escalating capital costs. The silver refinery could come on stream as much as two years later, although there is a possibility it will open simultaneously with the copper refinery. It is anticipated that the silver refinery will ultimately have an annual capacity of 311 000 to 373 000 kilograms (10-12 million ounces) of refined silver. This capacity should be sufficient to process the silver content of the copper concentrates at maximum planned production.

Mattagami Lake Mines Limited continued development work at its Lyon Lake property about 8 kilometres east of the Mattabi mine in the Sturgeon Lake area of northwestern Ontario. Construction of the surface plant has been completed and work is continuing on the 475-metre shaft being sunk to develop the five known ore zones on the property. Ore production at a rate of 900 tonnes a day is expected to begin early in 1978, when spare capacity will be available at the concentrator owned by nearby Mattabi Mines Limited. At December 31, 1976, geological ore reserves amounted to 3 656 000 tonnes averaging 6.66 per cent zinc, 1.15 per cent copper, 0.63 per cent lead, and 116.23 grams of silver and 0.31 gram of gold a tonne.

Manitoba-Saskatchewan. In Manitoba and Saskatchewan much of the silver continued to come from several base-metal mines operated by Hudson Bay Mining and Smelting Co., Limited near Flin Flon and Snow Lake, Manitoba. Significant quantities were also derived from the Fox and Ruttan copper-zinc mines operated by Sherritt Gordon Mines Limited at Lynn Lake and Ruttan, Manitoba, respectively. Development work continued at Hudson Bay's Centennial mine, 15 kilometres southeast of Flin Flon, where an orebody of 1 270 000 tonnes has been indicated to a depth of 365 metres. The orebody grades

2.06 per cent copper, 2.6 per cent zinc and 24.00 grams of silver and 1.37 grams of gold a tonne, and is still open at depth. It was expected that full production would begin at the Centennial mine about mid-1977. Development work also continued at Hudson Bay's Westarm mine on the west arm of Schist Lake about 15 kilometres south of Flin Flon, Manitoba. Diamond drilling has outlined reserves of 644 000 tonnes of copper ore to the 425-metre horizon, with the deposit still open at depth.

To meet operating restraints and adverse market conditions Sherritt Gordon Mines Limited decided to cut back ore production at both its Ruttan and Fox mines. The planned annual rate of production at the Ruttan mine was decreased from 2 800 000 to 2 540 000 tonnes commencing December 1975. Ore output at the Fox mine was reduced by about 25 per cent, effective mid-March 1976. The decreases in ore production at these two mines resulted in lower byproduct silver output in 1976.

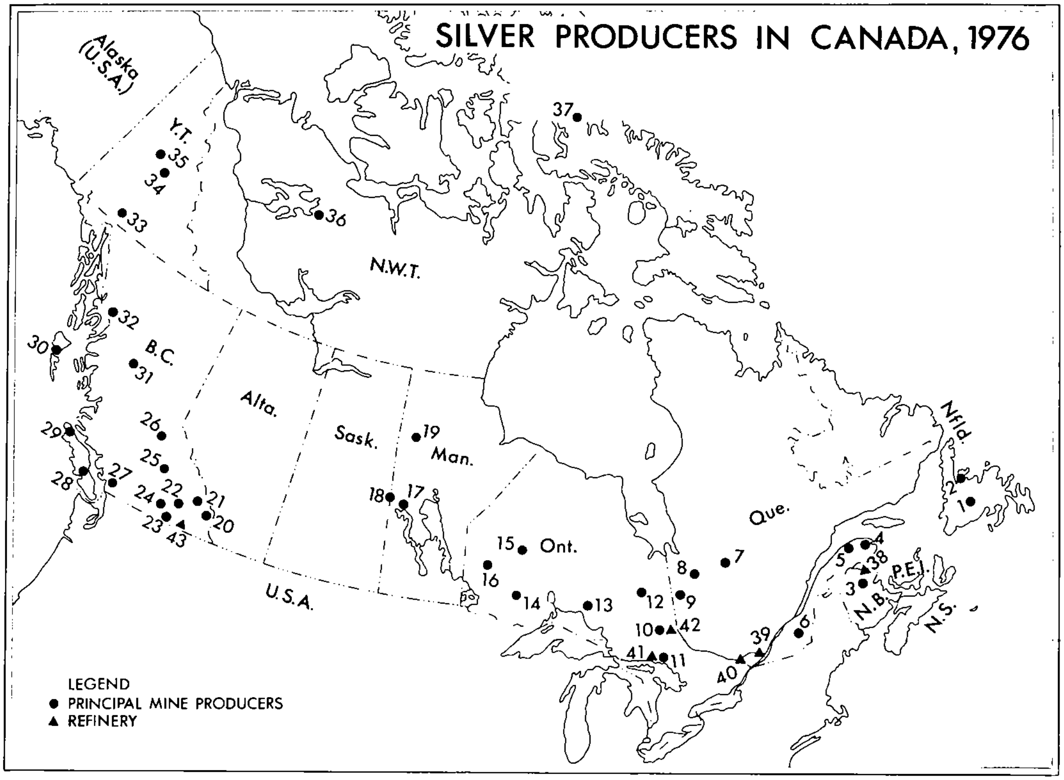
British Columbia. Base-metal ores continued to be the main source of British Columbia's mine output of silver. Cominco Ltd., the largest silver producer in the province, derived its output from the lead-zinc-silver ores of its Sullivan mine and from purchased ores and concentrates. Byproduct silver output from the Sullivan mine was considerably higher in 1976 than in 1975 because of the higher grade and greater tonnage of ore processed. Because of lower copper prices and the depressed condition of the world copper market, some of British Columbia's large copper producers continued to operate at curtailed rates of production in 1976, with the result that byproduct silver output at some of these porphyry copper mines continued to be lower than usual.

Making its initial contribution to British Columbia's silver production was Northair Mines Ltd. that began tune-up operations about May 1976 at its 270-tonne-a-day concentrator at its Brandywine Falls silver-gold-base-metals property 113 kilometres north of Vancouver. The mine is a multivein deposit, with gold being the major metal. It was the first new metal mining and milling operation to come into production in British Columbia since 1972. Total ore reserves in the various ore zones have been estimated at 417 000 tonnes averaging 120.0 grams of silver and 15.8 grams of gold a tonne, with additional values in copper, lead and zinc.

A feasibility study was completed about mid-1976 on Equity Mining Corporation's Sam Goosly silver-gold-copper property 65 kilometres south of Smithers, British Columbia. The company is now considering plans to bring the property into production in 1979 at a rate of 3 000 to 4 500 tonnes of ore a day if suitable arrangements can be made to obtain senior financing. Reserves of ore mineable by open-pit methods have been estimated at 39.5 million tonnes, grading 95.3 grams of silver and 0.89 gram of gold a tonne, and 0.33 per cent copper. Equity Mining, and Congdon and Carey Company of Denver, Colorado, share equally a 70 per cent working interest in the property, with Kennco Explorations (Western) Limited, a subsidiary of Kennecott Copper Corporation, holding a 30 per cent carried interest. The undertaking is managed by Equity Mining.

Early in 1977 Placer Development Limited considered taking an interest in the Sam Goosly property and assuming responsibility for bringing it into production. Later, however, Placer withdrew its support for the project. About mid-1977 Equity Mining began negotiating with Granby Mining Corporation of Vancouver and Boliden Aktiebolag of Stockholm, Sweden with a view toward these two companies participating in arrangements to bring the property into production. Terms of an agreement among the three companies were expected to be concluded early in 1978 and it was reported that they included provision for construction of a 4 170-tonne-a-day mining and milling complex costing about $60 million. The proposed development includes an open-pit mine and concentrator. Design and construction of the facilities would be the responsibility of Granby Mining. Access to the property would be through construction of a road from Houston, which is 37 kilometres northwest of the property. Wright Engineers Limited of Vancouver have been retained to assist in the engineering phase of the project. It is expected that the major financing of the project would be provided by Canadian chartered banks. Terms under negotiation include acquisition by Granby and Boliden of a substantial minority interest in Equity Mining, which owns the property, through purchase of new shares to be issued by Equity.

Yukon Territory. Mine production of silver in 1976 was much lower than in 1975 because of labour strikes that plagued all three producers. A two-month strike ended late in September at the silver-lead-zinc property of United Keno Hill Mines Limited at Elsa, which in 1975 was Canada's fourth-largest mine producer of silver with output of over 93 300 kilograms contained in lead and zinc concentrates. In the first quarter of 1976 ore production at the silver-lead-zinc mine of Cyprus Anvil Mining Corporation at Faro, Y.T., was reduced because of labour slowdowns and work stoppages during negotiations for new collective bargaining agreements with the office and technical workers. Then on July 30, 1976 operations were again suspended when the operating personnel went on strike in protest over a ruling of the Anti-Inflation Board (AIB) which ordered wage rollbacks in collective agreements that had already been negotiated between the company and the two locals of the United Steelworkers of America. This strike did not end until November 22 when the Union members ratified a new three-year agreement which expires September 30, 1978. Because of these interruptions, Cyprus Anvil's silver output in 1976 was over 50 per cent less than that of 1975. Byproduct silver output also declined at the



Principal Mine Producers
(numbers refer to numbers on map above)

1. ASARCO (Buchans Unit)
2. Consolidated Rambler Mines Limited
3. Brunswick Mining and Smelting Corporation Limited (nos. 12 and 6 mines)
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
4. Gaspé Copper Mines, Limited
5. Madeleine Mines Ltd.
6. Sullivan Mining Group Ltd., Cupra Division and D'Estrie Mining Company Ltd.
7. Campbell Chibougamau Mines Ltd.
   Falconbridge Copper Limited, Opemiska Division
   Lemoine Mines Limited
   Patino Mines (Quebec) Limited
8. Mattagami Lake Mines Limited
   Orchan Mines Limited
9. Falconbridge Copper Limited, Lake Dufault Division
   Manitou-Barvue Mines Limited
   Noranda Mines Limited, Horne Division
10. Agnico-Eagle Mines Limited
    Canadaka Mines Limited
    Teck Corporation Limited, Silverfields Division
11. Falconbridge Nickel Mines Limited
    Inco Limited
12. Texasgulf Canada Ltd., Kidd Creek mine
13. Noranda Mines Limited, Geco Division
    Willroy Mines Limited
14. Falconbridge Copper Limited, Sturgeon Lake Joint Venture
    Mattabi Mines Limited
15. Union Miniere Explorations and Mining Corporation Limited, Thierry mine
16. Selco Mining Corporation Limited, South Bay Division
17. Hudson Bay Mining and Smelting Co., Limited (Anderson Lake, Centennial, Chisel Lake, Osborne Lake, and Stall Lake mines)
18. Hudson Bay Mining and Smelting Co., Limited (Flin Flon, Ghost Lake, Schist Lake and White Lake mines)
19. Sherritt Gordon Mines Limited (Fox and Ruttan mines)
20. Cominco Ltd. (Sullivan mine)
21. Kam-Kotia Mins Limited (Silmonac mine)

22. Brenda Mines Ltd.
    Similkameen Mining Company Limited
23. Granby Mining Corporation, Phoenix Copper Division
24. Teck Corporation Limited (Beaverdell mine)
25. Bethlehem Copper Corporation
    Lornex Mining Corporation Ltd.
26. Gibraltar Mines Ltd.
27. Northair Mines Ltd.
28. Western Mines Limited
29. Utah Mines Ltd.
30. Wesfrob Mines Limited
31. Granisle Copper Limited
32. Newmont Mines Limited
33. Whitehorse Copper Mines Ltd.
34. Cyprus Anvil Mining Corporation
35. United Keno Hill Mines Limited
36. Echo Bay Mines Ltd.
    Terra Mining and Exploration Limited
37. Nanisivik Mines Ltd.

Refineries

(numbers refer to numbers on the map)

38. Brunswick Mining and Smelting Corporation Limited, Smelting Division
39. Canadian Copper Refiners Limited
40. Royal Canadian Mint
41. Inco Limited
42. Canadian Smelting & Refining (1974) Limited
43. Cominco Ltd.

copper-silver property of Whitehorse Copper Mines Ltd. near Whitehorse, Y.T., as a result of a two-month strike that began June 30, 1976.

Cyprus Anvil's exploration program in 1976 in the Anvil district of the Yukon Territory was highlighted by the discovery of a new lead-zinc-silver sulphide zone on its DY claims 19 kilometres southeast of its Faro mine. The zone was encountered by diamond drilling as part of the deep-drilling program commenced in 1975 and was on a geological projection of the host rocks that contain the Vangorda-Grum deposits controlled by Kerr Addison Mines Limited. A substantial follow-up drilling program is being planned.

Kerr Addison Mines Limited continued exploration and development work at the Grum zinc-lead-silver deposit in the Vangorda Creek area, about 13 kilometres southeast of the Cyprus Anvil operation near Faro. The initial $6.25 million exploration program provided data for a production feasibility study. The Grum Joint Venture is owned 60 per cent by Kerr Addison and 40 per cent by Canadian Natural Resources Limited (formerly Aex Minerals Corporation). In 1976 underground headings were driven and a considerable amount of underground diamond drilling was done. Metallurgical testing and environmental studies are also being carried out. Late in 1976 the deposit was reported to contain about 34.9 million tonnes averaging 6.69 per cent zinc, 4.23 per cent lead and 64.46 grams of silver a tonne. Mining methods being considered include a combination of open-pit and underground operations. Expenditures on the project by the joint venture to December 31, 1976 totalled approximately $12 million.

Northwest Territories. Silver output in the Northwest Territories was significantly higher in 1976 than in 1975 because of greater output by the two main producers, Echo Bay Mines Ltd. and Terra Mining and Exploration Limited. Both companies operated their silver-copper properties, near Port Radium on the east shore of Great Bear Lake, free of labour strikes during 1976.

On Baffin Island operations began on schedule late in 1976 at the first commercial mine in North America north of the Arctic Circle. It is the lead-zinc-silver property of Mineral Resources International Limited (MRI) at Strathcona Sound, 800 kilometres north of the Arctic Circle, in which Texasgulf Inc. has a 35 per cent carried interest. The property is operated by Nanisivik Mines Ltd. Nanisivik is owned 59.5 per cent by MRI, 18.0 per cent by the Canadian government and 11.25 per cent each by Metallgesellschaft A.G. of West Germany and Billiton B.V. of the Netherlands. When tune-up operations began at the Nanisivik concentrator early in October, ore was being fed to the mill at just under its rated capacity of 1 360 tonnes a day. Total cost of completing the project has been estimated at $60 million, exclusive of working capital. Ore reserves have been estimated at some 6.4 million tonnes averaging 14.1 per cent zinc, 1.4 per cent lead and 61.71 grams of silver a tonne.

Encouraging results were obtained by Texasgulf Inc. from additional diamond drilling done in 1976 on its major zinc-copper-lead-silver deposit discovered in 1975 in the Izok Lake area about 360 kilometres north of Yellowknife in the Northwest Territories. Preliminary ore tonnages have been calculated on the basis of results from 67 holes drilled in the first half of 1976 on the three sulphide zones comprising the deposit. It occurs partly under Izok Lake and partly under a 230-metre-long island in the southern portion of the lake. Ore tonnages have been calculated at over 10.9 million tonnes assaying 13.7 per cent zinc, 2.82 per cent copper, 1.42 per cent lead and 70.3 grams of silver a tonne. The deposit is shallow and ideal for open-pit mining. At Hood River, 40 kilometres north of Izok Lake, the company has outlined a deposit of about one million tonnes of high copper, low zinc and some silver mineralization. Another important zinc and copper showing was found at Point Lake, 77 kilometres south of Izok Lake. Geologic mapping, geophysical surveys and diamond drilling continued on land in the latter part of 1976 and a further program of drilling from lake

Table 8. Annual average silver prices: Canada, United States and United Kingdom, 1967-76

	Canada	United States Handy & Harman, New York	United Kingdom London Spot	United Kingdom London Spot
	($ Can.)	($ U.S.)	(pence)	($ U.S. equiv.)[3]
		(per troy ounce)		
1967	1.725	1.550	141.977	1.626
1968	2.311	2.145	219.529	2.189
1969	1.931	1.791	180.774	1.800
1970	1.851	1.771	177.068	1.768
1971	1.571	1.546	63.086[2]	1.542
1972	1.671	1.685	67.403[2]	1.686
1973	2.567	2.558[1]	103.783[2]	2.544
1974	4.595	4.708	199.819[2]	4.675
1975	4.503	4.419	200.118[2]	4.446
1976	4.291	4.353	242.423[2]	4.377

Sources: Canadian prices are those quoted by *The Northern Miner* (arithmetical average of daily quotations). United States and United Kingdom prices are those quoted by *Metals Week*.
[1]The 60-day general price freeze in effect in the United States from June 13 through August 12, 1973 forced intermittent suspension of Handy and Harman's daily quotation during July and August for a total of 22 days. [2]1971-76 prices are expressed in new British pence, following British conversion to decimal currency, February 11, 1971, at the rate of 100 pence per pound sterling. Previous rate was 240 pence per pound. [3]Prices have been converted at the yearly average exchange rates quoted by *Metals Week*.

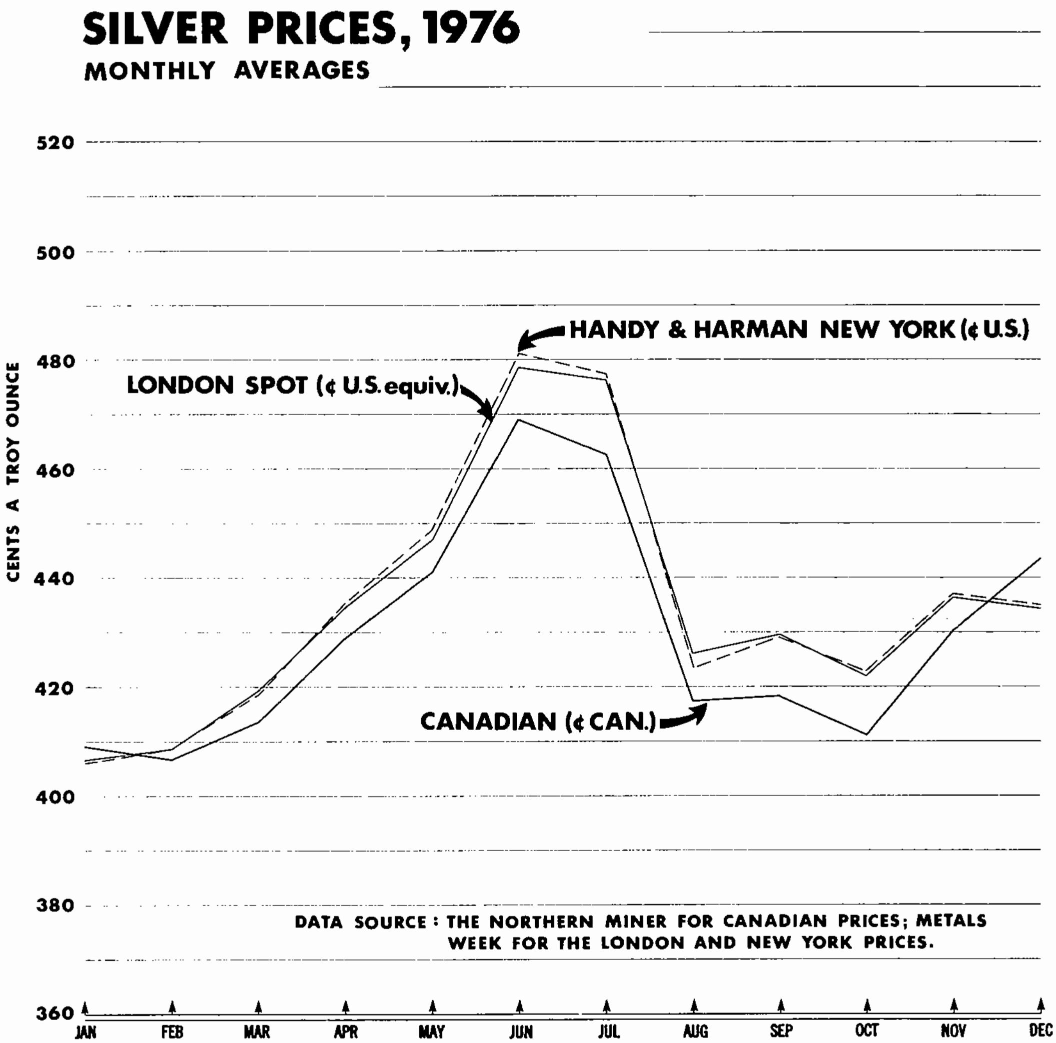
concepts, for heating homes and buildings. Substitutes for silver include super-purity aluminum, and copper; in fact aluminum has been used on an experimental basis as a collector of sun rays for heating purposes. However, the coefficient of reflectivity of both aluminum and copper is lower than that of silver, based on wave lengths of the sun's light rays in the visible range. For the same reason, it it not thought that the platinum group metals will be used for this application. Studies indicate that the solar energy derived from a silver-using process requires about one-third less power to produce than a similar process using aluminum. There are now four major United States companies competing in the field of solar energy research and development, namely McDonnell Douglas Aeronautics, Martin Marietta Corporation, Rockwell International Corp. and Boeing Aircraft.

Silver is being used increasingly with tin in low-temperature soldering applications. Comparisons of the mechanical properties of 95 per cent tin-5 per cent silver solders with 80 per cent lead-20 per cent tin solders, show that both the ultimate tensile strength and the shear strength of the silver-containing solders are approximately twice that of the lead-tin products. The silver solders are also about 30 per cent harder, and elongate less than one-fourth as much as the lead-tin solders when the end products have to withstand stress, impact or heat. Also, tin-silver solders are non-toxic, which is an essential consideration for joints that come in contact with food or drink. Applications today vary from plumbing, heating, refrigeration and air conditioning, to food service and processing utensils, holloware and the electronics industry. Because of the non-toxicity of tin-silver solders, this application could result in significant increases in silver usage in countries where the laws on toxicity might be made more stringent.

While silver has been used for years in dentistry, Russian and Japanese experts have reportedly developed a non-toxic silver amalgam with gallium to fill cavities in teeth. Also, researchers have recently unveiled a cyanide-free silver electroplating solution. The new product is said to be comparable to the best available silver baths containing cyanide. In addition to being able to comply with antipollution measures, the non-cyanide silver solution is believed to have good electroplating qualities.

Prices

In 1976 the New York Handy & Harman silver price displayed another year of volatility. On January 5 the opening price was $U.S. 4.240 an ounce. A low of $3.815 obtained on January 26 and a high of $5.100 was reached on July 6; at year-end the price was $4.375. Average for the year was $4.353. The London spot silver price ranged between a low of 189.1 pence an ounce, equivalent to $U.S. 3.830, on January 21, and a high of 282.2 pence ($U.S. 5.025) on July 9. At year-end the price was 255.7 pence ($U.S. 4.355). Average for the year was 242.4 ($U.S. 4.377). In 1976 the Canadian silver price closely followed its United States counterpart, with the essential difference being the currency exchange rate. It fluctuated between a low of $ Can. 3.817 an ounce on January 26 and a high of $4.949 on July 6. At year-end the price was $4.436. Average for the year was $4.291.


SILVER PRICES, 1976
MONTHLY AVERAGES
HANDY & HARMAN NEW YORK (¢ U.S.)
LONDON SPOT (¢ U.S. equiv.)
CANADIAN (¢ CAN.)
CENTS A TROY OUNCE
520
500
480
460
440
420
400
380
360
DATA SOURCE: THE NORTHERN MINER FOR CANADIAN PRICES; METALS WEEK FOR THE LONDON AND NEW YORK PRICES.
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Ores of metals, nop	free	free	free	free
35800-1	Anodes of silver	free	free	10%	free
35900-1	Silver in ingots, blocks, bars, drops, sheets or plates, unmanufactured; silver sweepings	free	free	free	free
35905-1	Scrap silver and metal alloy scrap containing silver[1]	free	free	25%	free
36100-1	Silver leaf[2]	12½%	20%	30%	12½%
36200-1	Articles consisting wholly or in part of sterling or other silverware, nop; manufactures of silver, nop (expires June 30, 1984)	17½%	22½%	45%	15%

United States

Item No.		Non-communist countries	Communist countries except Yugoslavia
420.60	Silver compounds	5%	25%
601.39	Precious metal ores, silver content	free	free
605.20	Silver bullion, silver dore and silver precipitates	free	free
605.46	Platinum-plated silver, unwrought or semimanufactured	16%	65%
605.47	Gold-plated silver, unwrought or semimanufactured	25%	65%
605.48	Other unwrought or semimanufactured silver	10.5%	65%
605.65	Rolled silver, unworked or semimanufactured	10.5%	65%
605.70	Precious metal sweepings and other precious metal waste and scrap, silver content	free	free
644.56	Silver leaf	2.5¢ per 100 leaves	5¢ per 100 leaves

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976), TC Publication 749.
[1]British Preferential, Most Favoured Nation and General tariffs expire October 31, 1978; General Preferential tariff expires June 30, 1978. [2]General Preferential tariff expires June 30, 1984.
nop — Not otherwise provided for.

Sodium Sulphate

A.F. KILLIN

Sodium sulphate is an industrial chemical used principally in the manufacture of pulp and paper by the "kraft" process, in detergents, and in glass. It can be produced from natural brines and deposits in alkaline lakes in areas with dry climates and little or no drainage, from subsurface deposits and brines, or as a byproduct of chemical processes. Canada's sodium sulphate industry is based on natural brines and deposits in many alkaline lakes in the southern prairies of Saskatchewan and Alberta. Nine plants operated in Canada in 1976. Small quantities of byproduct sodium sulphate are recovered at a viscose-rayon plant and at a pulp and paper mill in Ontario, and at a strontium sulphate-carbonate plant in Nova Scotia.

In the United States, naturally occurring sodium sulphate is produced in California, Texas and Utah, and byproduct material in the eastern states.

Production and developments in Canada

Shipments of sodium sulphate from Canadian producers increased to 490 000 tonnes in 1976, almost 4 per cent more than in 1975. The value of shipments increased 12.8 per cent over 1975 to $24 878 000. Production was lower at the plants in Saskatchewan because of operating difficulties and the closure of one plant during the year. The Saskatchewan Department of Mineral Resources reports Saskatchewan production of sodium sulphate at 416 861 tonnes* in 1976.

Deposits. In addition to the lakes in Saskatchewan and Alberta, sodium sulphate has been found in association with magnesium sulphate in lakes in British Columbia and with calcium sulphate in deposits in New Brunswick. Only minor production has been obtained in British Columbia and none in New Brunswick from deeply buried deposits of glauberite, the anhydrous double sulphate of sodium and calcium.

The sodium sulphate deposits in Saskatchewan and Alberta have formed in shallow, undrained lakes and ponds where in-flow is greater than out-flow. Percolating ground waters carry dissolved salts into the basins from the surrounding soils. High rates of summer evaporation concentrate the brine and cooler fall temperatures cause crystallization and precipitation of sodium sulphate as mirabilite ($Na_2SO_4 \cdot 10H_2O$). The cycle has been repeated year after year and thick deposits of hydrous sodium sulphate, accompanied by mud and other salts, have accumulated. Occasionally, where sodium chloride is present, some of the sodium sulphate is precipitated as thenardite (Na_2SO_4), the anhydrous variety of the salt.

Some lakes have not accumulated thick beds because the crystals of sodium sulphate deposited in the fall and winter are redissolved each spring, to re-form a brine rich in sodium sulphate. These same lakes commonly contain a high concentration of magnesium sulphate, a mineral that may prove valuable in the future.

Deposits in Saskatchewan have been identified that contain, in total, approximately 90 million tonnes of anhydrous sodium sulphate. Of this amount, a total of about 51 million tonnes is in 21 individual deposits each containing more than 544 300 tonnes of sodium sulphate. One deposit in Alberta contains 2.7 million tonnes of Na_2SO_4.

Recovery and processing. Because sodium sulphate is recovered by evaporation of concentrated brines or by dredging of the permanent beds of crystal, weather is as important for recovery of sodium sulphate as it is for its deposition. A large supply of fresh water is also essential. One method of sodium sulphate recovery is to pump lake brines that have been concentrated by hot summer weather into evaporating ponds or reservoirs. Continued evaporation produces a saturated or near-saturated solution of mirabilite. Differential crystallization occurs in the fall when the solution cools. Hydrous sodium sulphate crystallizes and precipitates, whereas sodium chloride, magnesium sulphate and other impurities remain in solution. Before freezing weather sets in, the impure solution remaining in the reservoir is drained or pumped back into the source lake. After the crystal bed has become frozen, harvesting is carried out using conventional earthmoving equipment. The harvested crystal is stockpiled adjacent to the plant.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Canada, sodium sulphate production and trade, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Production				
Shipments	472 196	22 048 515	490 000	24 878 000
Imports				
Total salt cake and Glauber's salt				
United States	7 191	318 000	12 148	711 000
Belgium and Luxembourg	7 690	382 000	9 713	465 000
United Kingdom	7 753	276 000	7 405	365 000
Netherlands	4	4 000	—	—
Total	22 638	980 000	29 266	1 541 000
Exports				
Crude sodium sulphate				
United States	170 436	7 326 000	145 463	8 139 000
New Zealand	2 224	240 000	837	99 000
Liberia	—	—	87	6 000
Cuba	—	—	9	1 000
Thailand	1 633	148 000	—	—
Trinidad-Tobago	784	86 000	—	—
Other countries	3 032	229 000	—	—
Total	178 109	8 029 000	146 396	8 245 000

Source: Statistics Canada.
[p] Preliminary; — Nil.

In Saskatchewan, three operators: Francana Minerals Ltd. at Snakehole Lake, Ormiston Mining and Smelting Co. Ltd. at Horseshoe Lake, and Sybouts Sodium Sulphate Co., Ltd. at East Coteau Lake, use floating dredges to mine the permanent crystal bed. The slurry of crystal and brine is transported to a screening house at the plant by pipeline. If sufficiently concentrated, the brine from the screens is collected in an evaporation pond.

The Ingebrigt Lake plant of Saskatchewan Minerals uses a combination of dredging and solution mining and pumps a concentrated brine to an aircooled crystallizer at the plant. In Alberta, Alberta Sulphate Limited uses solution-mining techniques at Horseshoe lake near Metiskow.

Processing of the natural salt consists of dehydration (Glauber's salt contains 55.9 per cent water of crystallization) and drying. Commercial processes used in Saskatchewan include rotary kilns, Holland evaporators, submerged combustion and multiple effect evaporators. Auxiliary equipment includes screens, classifiers, centrifuges, rotary kiln driers and crushers. Salt cake, the product used principally in the pulp and paper industry, contains a minimum of 97 per cent Na_2SO_4. Detergent grade material analyzes up to 99.77 per cent Na_2SO_4. Uniform grain size and free flow are important in material handling and use.

Production and performance at all plants was affected in 1976 by excess brine in the lakes. Concentrations were not sufficiently high to allow efficient recovery in either the brining or dredging operations. Plants that had sold off stockpiles in the peak-demand years of 1973 and 1974 were not able to replenish them. Operations at Sybout's plant were halted in the spring, and the summer season was used for plant maintenance and rehabilitation. Francana installed a bucket wheel cutter on the dredge at Snakehole Lake and officials claim improved efficiency. Production from the dredge was hampered by the fact that the dilute brine dissolved the dredged crystals in the pipeline and this reduced plant feed. A saving factor was an increased quantity of concentrated brine delivered to the evaporation ponds.

By-and co-product recovery. In 1976, Courtaulds (Canada) Limited produced between 13 000 and 18 000 tonnes of byproduct detergent grade, sodium sulphate from its viscose-rayon plant at Cornwall, Ont. Ontario Paper Company Limited produced about 35 000 tonnes of saltcake from a byproduct recovery unit at its paper plant at Thorold, Ont.

Kaiser Aluminum & Chemical of Canada Limited, a subsidiary of Kaiser Aluminum & Chemical Canada Investment Limited, continued to recover coproduct

Table 2. Canada, sodium sulphate production, trade and consumption, 1965, 1970, 1974-76

	Production[1]	Imports[2]	Exports	Consumption
	(tonnes)			
1965	313 404	26 623	105 546	250 038
1970	445 017	26 449	108 761	369 054
1974	638 179	22 519	236 715	305 365
1975	472 196	22 638	178 109	256 385
1976[p]	490 000	29 266	146 396	. .

Source: Statistics Canada.
[1]Producers' shipments of crude sodium sulphate; [2]Includes Glauber's salt and crude salt cake.
[p]Preliminary; . . Not available.

Table 4. Canada, available data on sodium sulphate consumption, 1974-76

	1974	1975	1976
	(tonnes)		
Pulp and paper	246 211	. .	. .
Soaps	25 849	. .	. .
Glass and glass wool	11 693	. .	. .
Other products[1]	21 612	. .	. .
Total	305 365	256 385	. .

Source: Statistics Canada, breakdown by Mineral Development Sector.
[1]Colours, pigments, foundries, feed supplements and other minor uses.
. . Not available.

Table 3. Canada, natural sodium sulphate plants, 1976

	Plant Location	Source Lake	Annual Capacity
			(tonnes)
Alberta			
Alberta Sulphate Limited	Metiskow	Horseshoe	90 700
Saskatchewan			
Francana Minerals Ltd.	Grant	Snakehole	90 700
Francana Minerals Ltd.	Hardene	Alsask	45 350
Midwest Chemicals Limited	Palo	Whiteshore	109 000
Ormiston Mining and Smelting Co. Ltd.	Ormiston	Horseshoe	90 700
Saskatchewan Minerals	Chaplin	Chaplin	135 000
Saskatchewan Minerals	Bishopric	Frederick	35 000
Saskatchewan Minerals	Fox Valley	Ingebrigt	135 000
Sybouts Sodium Sulphate Co., Ltd.	Gladmar	East Coteau	45 350
Total			776 800

Source: Company reports.

salt cake from its strontium carbonate plant at Point Edward, Nova Scotia. Continued financial losses and the lack of development of markets for strontium carbonate has led to a decision by Kaiser to close the plant in 1977.

Consumption and trade

There are three main users of sodium sulphate: the kraft pulp and paper industry, the detergent industry and the glass industry. Other users include the dyeing industry and producers of mineral-feed supplements and chemical products. Consumption in the pulp and paper industry has stabilized and, with the introduction of closed-circuit pulp mills, reduced use of sulphates in the pulping process and increased recovery efficiencies, it is probable that the consumption of sodium sulphate in this industry will decline. There is some possibility for growth in consumption by the detergent industry.

Over 90 per cent of Canada's exports go to the United States. The expansion of the Kerr-McGee facility at Trona, California by 122 000 tonnes a year could have a depressing effect on Canadian exports to the United States market. Total exports at 146 396 tonnes were 18 per cent lower than in 1975. Imports at 29 266 tonnes were 6 628 tonnes higher than in 1975.

Outlook

Increased emphasis on quality requirements (97+ per cent Na_2SO_4) and a trend toward reduction of use in the pulp and paper industry, coupled with a possible reduction in exports, gives a depressed outlook for sales of salt cake. It is probable that increased demand for detergent-grade material will provide the only market improvement in 1977.

Prices

Prices of sodium sulphate fob works for salt cake remained steady at $49.60 a tonne, bulk carload lots for the year. The price of detergent grade rose from $96.35 a tonne in January to $127.30 a tonne, bulk carload lots, in March, where it remained for the rest of the year.

Canadian prices of sodium sulphate, as quoted by Canadian Chemical Processing Buyers Guide, November 1976.

	($ Canadian per metric ton)
Sodium sulphate (salt cake) Bulk, carlots, fob works	$ 49.60
Detergent-grade bulk, fob works	$127.30

United States prices according to Chemical Marketing Reporter, December, 1976.

	($ U.S. per metric ton)
Salt cake, 100% Na_2SO_4 basis, fob plant east	$71.65
Same basis, west	$60.65
Sodium sulphate, detergent rayon-grade, bags, carlots, works East	$77.20

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General
21000-1	Natural sodium sulphate	10%	15%	25%

United States

Item No.		
421-42	Crude sodium sulphate (salt cake)	Free
421-44	Anhydrous	40¢ per long ton
421-46	Crystallized (Glauber's salt)	80¢ per long ton

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa, For United States, Tariff Schedules of the United States Annotated (1975), TC Publication 706.

Stone

D.H. STONEHOUSE

Naturally occurring rock material quarried or mined for industrial use with no change in its chemical state and with its physical character altered only by shaping or by sizing is commercially termed "stone". Dimension stone is shaped for use as a building block, slab or panel. It may be rough-cut, sawn or polished, and its application may depend on its strength, hardness, durability and ornamental qualities. Broken irregular, screened and sized pieces constitute the crushed stone category. It is used mainly as an aggregate in concrete and asphalt, in highway and railway construction and as heavy riprap for facing wharves and breakwaters.

Stone production in Canada, either as dimension stone or crushed stone, is used directly or indirectly by the construction industry, except for small amounts used in the manufacture of monuments. Indirect usage includes that portion of the resource that is utilized in the manufacture of lime, cement, iron and steel, all of which are associated with various phases of the construction industry. Activity in both building construction and heavy or engineering construction can be indicative of demands for quarried stone.

The large number of stone-producing operations in Canada precludes describing within this review individual plants or facilities. Many are part-time or seasonal operations, many are operated subsidiary to construction or manufacturing activities by establishments not classified to the stone industry, and some are operated directly by municipal or provincial government departments producing stone for their own direct use. Detailed information can be obtained through the individual provincial departments of mines or equivalent. Most provinces have accumulated data relative to occurrences of stone of all types and in many cases have published such studies. The federal government, through the Geological Survey of Canada, has also gathered and published a great number of geological papers pertaining to stone occurrences. Works by W.A. Parks[1] and by M.F. Goudge[2] have become classics in the fields of building stones and limestones, respectively.

Dimension stone. Granite, limestone, marble and sandstone are the principal rock types from which building and ornamental stone is fashioned. Construction uses account for over 85 per cent of the consumption of building and ornamental stone produced and sold in Canada; the remainder is used as monumental stone.

Today, in the building sector of the construction industry, granite, limestone and marble are used as facing stone in the form of cut and polished panels, in conjunction with steel and concrete, for institutional and commercial buildings. In residential buildings the use of a limestone or sandstone ashlar, or coursing stone, is becoming increasingly popular. The emphasis has changed from stone used for structural purposes to stone used for its aesthetic qualities. The architect and contractor can design and build for lasting beauty using Canadian building stone.

High costs associated with quarrying, finishing, transporting and placing dimension stone in the building construction sector have contributed to the erosion of this industry and have made market penetration by concrete products possible.

Crushed stone. Many quarries that produce crushed stone are operated primarily to produce stone for other purposes, e.g., granite for building blocks and monuments, limestone for cement or lime manufacture, or for metallurgical use, marble for monuments and building panels, sandstone for riprap, and cut stone. Quarries removing solid rock by drilling, blasting and crushing are not likely to be operated for small, local needs as are gravel pits and are, therefore, usually operated by large companies associated with the construction industry. Depending on costs and availability, crushed stone competes with gravel and crushed gravel as an aggregate in concrete and asphalt, and as railway ballast and road metal. In these applications it is subject to the same physical and chemical testing procedures as the gravel and sand aggregates.

Other uses for crushed stone include the manufacture of roofing granules from granite and marble, the production of poultry grit from limestone, silica and granite; and the production of rock wool from limestone and sandstone. Pulverized stone is used as follows: granite, limestone and sandstone as asphalt filler; limestone for dusting coal mines; and limestone and marble for agricultural application. Limestone is also produced for chemical and metallurgical uses in the iron and steel industry, the glass industry, the pulp and paper industry and in sugar manufacture.

Canadian industry

Atlantic provinces. *Limestone.* The many occurrences of limestones in the Atlantic provinces have been systematically catalogued during the past few years.[3,4,5] Deposits of commercial importance are being worked in three of the four provinces.

In Newfoundland limestone is available from small, impure exposures in the eastern portion of the island, from small, high-calcium deposits in the central region, and from large, high-purity, high-calcium occurrences in the west. Other than periodic operation to secure aggregate for highway work, the main exploitation is by North Star Cement Limited at Corner Brook.[6] Large quantities of high-calcium limestone have been outlined in the Port au Port district, most recently by Lehigh Portland Cement Company, Allentown, Pennsylvania, in association with British Newfoundland Exploration Limited (Brinex), with the objective of

Table 1. Canada, total production (shipments) of stone, 1974-76

	1974		1975		1976^p	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
By province						
Newfoundland	616 728	2 043 999	876 641	2 889 457	816 000	2 700 000
Prince Edward Island	—	—	—	—	—	—
Nova Scotia	1 511 190	4 585 868	1 581 382	4 637 276	1 451 000	4 400 000
New Brunswick	2 832 928	6 574 573	3 240 755	8 247 571	2 540 000	7 000 000
Quebec	50 013 435	88 239 227	50 763 421	110 409 777	51 710 000	117 000 000
Ontario	31 261 288	60 916 200	27 525 860	62 249 745	26 853 000	66 500 000
Manitoba	2 223 068	3 384 453	969 384	2 234 843	454 000	1 500 000
Alberta	163 343	892 096	235 145	1 158 980	181 000	1 200 000
British Columbia	4 211 074	10 570 662	4 221 023	10 896 391	3 175 000	9 300 000
Canada	92 833 054	177 207 078	89 413 611	202 724 040	87 180 000	209 600 000
By use						
Building stone						
Rough	78 730	2 018 794	72 833	2 058 987		
Dressed	—	—	—	—		
Monumental, ornamental stone						
Rough	28 219	1 330 541	32 316	1 508 639		
Dressed	—	—	—	—		
Flagstone	51 063[1]	518 876[1]	26 617[1]	648 831[1]		
Curbstone	—	—	—	—		
Paving blocks	—	—	—	—		
Chemical and metallurgical						
Cement plants, foreign	1 255 236	1 532 909	1 120 764	1 375 714		
Lining, open-hearth furnaces	364 190	526 296	350 960	583 798		
Flux in iron and steel furnaces	1 058 020	1 695 822	1 027 776	3 006 006		
Flux in nonferrous smelters	47 796	51 806	77 011	146 092		
Glass factories	219 510	1 138 389	294 860	1 810 879		
Lime kilns, foreign	291 585	798 522	255 330	792 887		
Pulp and paper mills	318 865	1 495 021	284 457	1 383 735		
Sugar refineries	57 289	206 326	67 806	282 369		
Other chemical uses	338 609	1 305 318	140 089	430 802		

Table 1 (concl'd)

	1974		1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
Pulverized stone						
Whiting (substitute)	11 556	345 546	13 499	459 986		
Asphalt filler	69 096	298 255	33 113	277 549		
Dusting, coal mines	4 031	46 439	4 332	73 639		
Agricultural purposes and fertilizer plants	773 017	3 561 939	904 750	4 603 496		
Other uses	587 174	1 554 945	703 940	2 674 155		
Crushed stone for						
Manufacture of artificial stone	46 360	258 765	15 952	188 127		
Roofing granules	214 083	4 591 140	198 170	4 962 399		
Poultry grit	58 070	428 439	63 770	429 194		
Stucco dash	27 131	816 015	23 222	865 176		
Terrazzo chips	10 854	422 778	9 403	285 367		
Rock wool	13 291	29 302	181	1 000		
Rubble and riprap	1 706 770	3 487 669	2 790 364	5 856 607		
Concrete aggregate	11 889 244	21 229 826	13 144 766	28 119 894		
Asphalt aggregate	7 170 692	13 661 520	6 448 373	13 490 655		
Road metal	31 897 775	53 705 056	32 807 692	68 893 302		
Railroad ballast	5 674 536	10 000 079	3 154 293	6 111 642		
Other uses	28 570 262	50 150 745	25 346 972	51 403 113		
Total	92 833 054	177 207 078	89 413 611	202 724 040		

Source: Statistics Canada.
[1]Includes flagstone, curbstone, paving blocks, etc.
[p]Preliminary; — Nil.

establishing a 1-million-tonne*-a-year portland cement facility in the region. A buoyant export market for portland cement or for clinker would be necessary in order to support a plant of such capability. Canada Cement Lafarge Ltd. of Montreal still maintains an active interest in high-calcium limestone deposits in this area as well.

In Nova Scotia limestones occur in the central and eastern parts of the province in thin, tilted lenses typical of deposits in Atlantic Canada and in contrast to deposits of much greater thickness and areal extent in central Canada.

Mosher Limestone Company Limited quarries a dolomitic limestone at Upper Musquodoboit, Nova Scotia. Pulverized material is sold for agricultural use throughout the Atlantic provinces. Sydney Steel Corporation (Sysco) produces a high-calcium, fossiliferous limestone at Irish Cove, Nova Scotia, and a high-purity dolomite at Frenchvale, Nova Scotia, for use in the Sydney steel plant. Studies to determine the viability of a lime-manufacturing plant in the Sydney area have been made in connection with incorporation of a basic oxygen process at the Sysco plant. Calpo Limited continues to supply sized, high-calcium limestone from an area near Antigonish Harbour to Scott Paper Limited at Abercrombie, and Canada Cement Lafarge Ltd. obtains limestone for portland cement manufacture on site at its Brookfield location.[6]

Drilling programs carried out by the province in an effort to attract appropriate industry to the Canso Strait area have indicated reserves of both high-calcium and dolomitic stone.

In New Brunswick, limestone is quarried at three locations — Brookville, Elm Tree and Havelock — for use as a crushed stone, as an aggregate, or for agricultural application. Brookville Manufacturing Company, Limited, Saint John, following an expansion program over the past four years, is now the largest supplier of coarse aggregate in southern New Brunswick and the company also supplies agricultural limestone. Havelock Lime Works Ltd. has expanded its plant to offer a range of products including washed, crushed and sized aggregates for asphalt and concrete application and finely pulverized filler material.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Havelock Processing Ltd. produces high-calcium lime at Havelock[7] and Canada Cement Lafarge Ltd. uses limestone at its Havelock plantsite in the production of portland cement[6].

Granite. Occurrences of granites in the Atlantic region have been described by Carr.[8] Current operations in Nova Scotia are at Nictaux, Shelburne and Erinville. A grey granite is produced from operations near Nictaux and from one quarry at Shelburne for use mainly in the monument industry. A black granite from Shelburne and a diorite from Erinville are used for monuments and for dimension stone. Quartzitic rock referred to as "bluestone" is quarried at Lake Echo, north of Dartmouth, for use as facing stone. Crushed quartzite for use as an aggregate is produced at a number of locations in Halifax County. At Folly Lake in Colchester County a diorite rock is quarried, mainly for use as railway ballast.

Granites are quarried intermittently from a number of deposits within New Brunswick to obtain stone of required colour and texture for specific application. A red, fine- to medium-grained granite is quarried near St. Stephen, and fine-grained, pink, grey and blue-grey granites are available in the Hampstead (Spoon Island) district. In the Bathurst area, a brown-to-grey, coarse-grained granite is quarried upon demand, as is a salmon-coloured, medium-grained granite near Antinouri Lake, and a black, ferro-magnesian rock in the Bocabec River area. Red granite is available in the St.

Table 2. Canada, production (shipments) of limestone, 1974-75

	1974		1975	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	400	1 208	645	1 924
Nova Scotia	177	500	163	581
New Brunswick	714	2 004	888	2 995
Quebec	37 829	61 302	39 864	81 232
Ontario	29 715	52 925	26 794	55 482
Manitoba	664	1 369	471	1 281
Alberta	142	871	139	1 017
British Columbia	3 125	7 439	3 320	8 010
Canada	72 766	127 618	72 284	152 522
By use	(tonnes)	($)	(tonnes)	($)
Building stone				
Rough	33 387	574 916	35 484	706 522
Dressed	—	—	—	—
Monumental and ornamental				
Rough	708	27 220	2 213	72 673
Dressed	—	—	—	—
Flagstone	5 370[1]	141 598[1]	7 369[1]	192 228[1]
Curbstone	—	—		
Paving blocks	—	—		
Chemical and metallurgical				
Cement plants, foreign	1 202 179	1 402 399	1 120 764	1 375 714
Lining, open-hearth furnaces	364 190	526 296	350 960	583 798
Flux, iron and steel furnaces	1 057 375	1 681 602	1 027 776	3 006 006
Flux, nonferrous smelters	47 796	51 806	77 011	146 092
Glass factories	219 510	1 138 389	294 860	1 810 879
Lime kilns, foreign	291 585	798 522	255 330	792 887
Pulp and paper mills	309 273	1 429 249	276 298	1 319 842
Sugar refineries	57 289	206 326	67 806	282 369
Other chemical uses	338 609	1 305 318	140 089	430 802
Pulverized stone				
Whiting substitute	11 556	345,546	13 499	459 986
Asphalt filler	64 501	282 200	28 248	258 726
Dusting coal mines	4 031	46 439	4 332	73 639
Agricultural purposes and fertilizer plants	705 083	3 242 800	801 292	4 072 306
Other uses	583 581	1 487 258	701 802	2 622 189

Table 2 (concl'd)

	1974		1975	
	(000 tonnes)	($000)	(000 tonnes)	($000)
Crushed stone for				
Artificial stone	24 358	86 400	1 814	40 000
Roofing granules	47 511	307 661	44 409	203 873
Poultry grit	55 046	402 265	63 224	418 400
Stucco dash	18 373	696 547	21 118	794 875
Terrazzo chips	—	—	—	—
Rock wool	13 291	29 302	181	1 000
Rubble and riprap	871 929	2 118 434	807 261	1 444 529
Concrete aggregate	9 292 700	14 480 848	11 026 967	22 089 495
Asphalt aggregate	4 488 379	7 987 737	4 743 703	9 785 145
Road metal	25 674 840	41 695 637	26 214 832	51 694 106
Railroad ballast	4 354 589	6 939 082	2 460 236	4 308 966
Other uses	22 629 492	38 185 903	21 695 154	43 534 540
Total	72 766 531	127 617 700	72 284 032	152 521 587

Source: Statistics Canada.
[1]Includes flagstone, curbstone, paving blocks, etc.
— Nil.

George district. Granite for use as a crushed stone is produced near Fredericton and near Moncton.

Sandstone. A medium-grained, buff sandstone is quarried at Wallace, Nova Scotia, for use as heavy riprap and for dimension stone applications. Recently, considerable tonnages were used in the reconstruction of the fortress at Louisbourg. Small deposits in many parts of the province are quarried periodically for local use.

In New Brunswick a red, fine- to medium-grained sandstone has been quarried in Sackville for use in construction of buildings on the Mount Allison University campus. Deposits are exploited from time to time throughout Kent and Westmorland countries for local projects and for highway work.

Quebec. *Limestone.* Limestone occurs in the St. Lawrence and Ottawa river valleys and in the Eastern Townships. Other major deposits in the province are located in the Lac Saint-Jean — Saguenay River area and in the Gaspe region. The limestones range in geologic age from Precambrian to Carboniferous and vary widely in purity, colour, texture and chemical composition.[2]

Quebec Department of Natural Resources listed 62 operating limestone properties in 1975[10] including portland cement and lime producers. Quarries are located near major market areas such as Montreal, Quebec City, Sherbrooke, Ottawa-Hull and Trois-Rivières and supply crushed stone to the construction industry, mainly for use in concrete and asphalt and as highway sub-grade. Four operations were listed as producers of building stone.

The pulp and paper, metallurgical and agricultural industries use substantial quantities of limestone. At Kilmar, in western Quebec, Dresser Industries Canada, Ltd., formerly Canadian Refractories Limited, mines a magnesite-dolomite ore from which it produces refractory-grade magnesia and magnesia products.

Portland cement was produced in 1976 at five plants[6] in Quebec with a combined annual capacity of just over 4 million tonnes. Four companies produce lime at four locations within the province.[7]

Limestone blocks and other shapes are produced for the construction trade in the Montreal region and at various locations throughout the province as the need arises. Marble has been produced in the Stukely and Philipsburg areas. Five operations are listed by the Quebec Department of Natural Resources.[10]

Granite. Nearly 60 per cent of Canada's granite production comes from Quebec from long-established operations in two general regions — one north of the St. Lawrence and Ottawa rivers, including the Lac Saint-Jean area, and one south of the St. Lawrence River. Precambrian rocks contain granites of various colours, compositions and textures. Quebec Bureau of Statistics listed 59 granite producers in 1975,[9] while the Quebec Department of Natural Resources indicated that 22 plants were processing granite as building or ornamental stone.[10] Many areas underlain by granite are too remote from transportation and markets to be economically attractive.

Sandstone. There are far fewer sandstone-producing operations in Quebec than there are producers of limestones and granites. Of 14 operations producing from sandstone resources only two are marketing

Table 3. Canada, production (shipments) of marble, 1974-75

	1974		1975	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Quebec	336	1 257	349	1 583
Ontario	8	361	7	260
Canada[1]	344	1 619	356	1 843
	(tonnes)	($)	(tonnes)	($)
By use				
Building stone				
Rough	—	—	—	—
Dressed	—	—	—	—
Chemical process stone				
Flux in iron and steel furnaces	645	14 220	—	—
Pulp and paper mills	9 592	65 772	8 159	63 893
Other uses	—	—	—	—
Pulverized stone				
Whiting	—	—	—	—
Agricultural purposes and fertilizer plants	67 934	319 139	103 458	531 190
Other uses	3 434	65 937	2 138	51 966
Crushed stone				
For manufacture of artificial stone	22 002	172 365	14 138	148 127
Roofing granules	2 289	33 476	1 760	21 014
Poultry grit	—	—	—	—
Stucco dash	5 542	28 688	—	—
Terrazzo chips	10 854	422 778	9 403	285 367
Rubble and riprap	423	14 585	—	—
Concrete aggregate	—	—	31 019	193 190
Railroad ballast	—	—	—	—
Road metal	144 187	356 267	92 306	302 250
Other uses	76 579	125 415	93 730	245 718
Total	343 481	1 618 642	356 111	1 842 715

Source: Statistics Canada.
[1]Individual figures may not add to totals because of rounding.
— Nil

flagstone and construction blocks, the rest are supplying crushed stone for general use as aggregate.[9,10]

Ontario. *Limestone.* Although limestones in Ontario range from Precambrian through Devonian, the major production comes from Ordovician, Silurian and Devonian deposits.[11,12] Of particular importance are the limestones and dolomites from the following geological sequences: the Black River and Trenton formations, extending from the lower end of Georgian Bay across southern Ontario to Kingston; the Guelph-Lockport Formation, extending from Niagara Falls to the Bruce Peninsula and forming the Niagara Escarpment; and the Middle Devonian limestone extending from Fort Erie through London and Woodstock to Lake Huron. Production of building stone, fluxstone and crushed aggregate from the limestones of these areas normally accounts for over 90 per cent of total stone production in Ontario.

Marble is widely distributed over southeastern Ontario and, according to the Ontario Ministry of Natural Resources reports, underlies as much as 100 square miles.[13]

Legislation now in effect in Ontario controls the development, operation and rehabilitation of existing pits and quarries, designates areas in which such operations may be started and provides for regulated sequential land use. The necessity for an advance

Table 4. Canada, production (shipments) of granite, 1974-75

	1974		1975	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	18	133	45	422
Nova Scotia	1	14	1	12
New Brunswick	1 965	4 299	2 056	4 533
Quebec	7 827	18 222	7 274	20 035
Ontario	1 523	7 255	711	6 112
Manitoba	1 559	2 015	499	954
Alberta	—	—	2	4
British Columbia	997	2 431	882	2 840
Canada[1]	13 890	34 370	11 470	34 913
By use	(tonnes)	($)	(tonnes)	($)
Building stone				
Rough	17 412	716 928	16 220	832 793
Dressed	—	—	—	—
Monumental and ornamental				
Rough	27 511	1 303 321	28 872	1 375 328
Dressed	—	—	—	—
Flagstone[2]	9 721	177,116	3 116	85 270
Curbstone	—	—	—	—
Lining open-hearth furnaces	—	—	—	—
Chemical uses				
Pulp and paper mills	—	—	—	—
Pulverized stone				
Asphalt filler	4 595	16 055	4 865	18 823
Other pulverized uses	—	—	—	—
Crushed stone for				
Artificial stone	—	—	—	—
Roofing granules	157 549	4 228 141	151 901	4 737 017
Poultry grit	642	11 080	546	10 794
Stucco dash	3 216	90 780	2 104	70 301
Rubble and riprap	830 264	1 347 553	641 143	1 791 004
Concrete aggregate	1 879 310	4 479 555	1 585 545	4 166 880
Asphalt aggregate	2 263 969	4 789 302	1 538 358	3 264 202
Road metal	4 460 340	8 293 473	5 258 405	13 662 500
Railroad ballast	1 041 959	2 480 388	344 265	1 059 936
Other uses	3 193 432	6 436 079	1 894 316	3 837 939
Total[1]	13 889 918	34 369 771	11 469 656	34 912 787

Source: Statistics Canada.
[1]Individual figures may not add to totals because of rounding. [2]Includes flagstone, curbstone, paving blocks, etc.
— Nil.

assessment of the total impact of all developments affecting land use is recognized in the total legislative package. Complications arise, however, because of the number of government levels implementing and administrating the legislation. In early 1976 the Ministry of Natural Resources established a "Mineral Aggregate Working Party" bringing together representatives of the provincial and municipal governments, aggregate producers, the Conservation Council of Ontario and the Niagara Escarpment Commission. The Working Party produced, for consideration of Cabinet, a document outlining steps toward a mineral aggregate resource management policy for Ontario. The recommendations are far-reaching and include proposed changes in current legislation that impinges on pit and quarry operation and land use. Mineral aggregate studies have been done over three major areas of Ontario; central, east and south, as part of a provincial program to determine the future availability of sand, gravel and crushed stone.

During 1975 portland cement was produced by four companies at a total of six locations in Ontario,[6] while eight companies operated a total of ten lime-producing facilities in the province.[7]

Granite. Granites occur in northern, northwestern and southeastern Ontario.[14] Few deposits have been exploited for the production of building stone because the major consuming centres are in southern and southwestern Ontario where ample, good-quality limestones and sandstones are readily available for building. The areas most active in granite building stone production have been the Vermilion Bay area near Kenora, the River Valley area near North Bay, and the Lyndhurst-Gananoque area in southeastern Ontario. Rough building blocks were quarried from a gneissic rock near Parry Sound, while at Havelock a massive red-granite rock was quarried.

Sandstone. Sandstone quarried near Toronto, Ottawa and Kingston has been used widely in Ontario as building stone.[15] Production is currently from the Limehouse-Georgetown-Inglewood district where Medina sandstone is quarried, and from the Kingston area where Potsdam sandstone is quarried. Medina sandstones vary from grey, through buff and brown to red,

Table 5. Canada, production (shipments) of sandstone, 1974-75

	1974		1975	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	187	691	140	492
Nova Scotia	1 333	4 072	1 418	4 044
New Brunswick	153	271	297	719
Quebec	2 301	4 876	1 862	5 174
Ontario	15	375	15	396
Alberta	. . .	3	4	9
British Columbia	—	—	18	46
Canada[1]	3 990	10 287	3 754	10 881
By use	(tonnes)	($)	(tonnes)	($)
Building stone				
Rough	27 931	726 950	21 129	519 672
Dressed	—	—	—	—
Monumental and ornamental	—	—	1 231	60 638
Flagstone[2]	35 972	200 162	16 132	371 333
Curbstone	—	—	—	—
Paving blocks	—	—	—	—
Pulverized stone				
Asphalt filler	—	—	—	—
Agricultural purposes and fertilizer plants	—	—	—	—
Crushed stone for				
Artificial stone	—	—	—	—
Roofing granules	6 734	21 862	100	495
Poultry grit	2 382	15 094	—	—
Terrazzo chips	—	—	—	—
Rubble and riprap	4 154	7 097	714 305	1 375 706
Concrete aggregate	681 346	1 698 767	501 235	1 670 329
Asphalt aggregate	418 345	884 481	166 312	441 308
Road metal	1 618 408	3 359 679	1 047 772	2 930 516
Railroad ballast	277 989	580 609	258 739	614 268
Other uses	916 497	2 792 716	1 026 402	2 896 380
Total[1]	3 989 757	10 287 417	3 753 357	10 880 645

Source: Statistics Canada.
[1]Individual figures may not add to totals because of rounding. [2]Includes flagstone, curbstone, paving blocks, etc.
— Nil; . . . Less than one thousand tonnes.

Table 6. Canada, production (shipments) of shale, 1974-75

	1974		1975	
	(000 tonnes)	($000)	(000 tonnes)	($000)
By province				
Newfoundland	12	12	46	52
Quebec	1 721	2 583	1 413	2 386
Alberta	21	18	91	128
British Columbia	89	701	—	—
Canada	1 843	3 314	1 550	2 566
By use	(tonnes)	($)	(tonnes)	($)
Chemical and metallurgical				
Cement plants, foreign	53 057	130 510	—	—
Pulverized stone				
Other uses	159	1 750	—	—
Crushed stone for				
Rubble and riprap	—	—	627 655	1 245 368
Concrete aggregate	35 888	570 656	—	—
Road metal	—	—	194 377	303 930
Railroad ballast	—	—	91 053	128 472
Other uses	1 754 259	2 610 632	637 365	888 536
Total[1]	1 843 361	3 313 548	1 550 450	2 566 306

Source: Statistics Canada.
[1]Individual figures may not add to totals because of rounding.
— Nil.

Table 7. Canada, production (shipments) of stone by types, 1965, 1970, 1973-75

	Granite		Limestone		Marble		Sandstone	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
1965	7 102 549	16 569 762	56 407 688	69 974 005	71 160	1 049 264	3 785 665	5 328 404
1970	4 388 270	15 231 891	52 522 637	67 563 790	56 096	350 903	2 112 794	4 133 708
1973	7 406 319	19 799 305	71 357 671	100 316 961	241 784	1 107 200	2 517 724	5 698 258
1974	13 889 918	34 369 771	72 766 531	127 617 700	343 481	1 618 642	3 989 757	10 287 417
1975	11 469 656	34 912 787	72 284 032	152 521 587	356 111	1 842 715	3 753 357	10 880 645

	Shale		Slate		Total[1]	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
1965	2 121 415	1 837 492	145 305	88 094	69 633 782	94 847 021
1970	180 087	695 458	—	—	59 259 884	87 975 750
1973	2 186 234	1 770 879	—	—	83 709 732	128 692 603
1974	1 843 361	3 313 548	—	—	92 833 054	177 207 078
1975	1 550 450	2 566 306	—	—	89 413 611	202 724 040

Source: Statistics Canada.
[1]Individual figures may not add to totals because of rounding.
— Nil.

and some are mottled. They are fine- to medium-grained. The Potsdam stone is medium-grained; the colour ranges from grey-white through salmon-red to purple, and it can also be mottled. Current uses are as rough building stone, mill blocks from which sawn pieces are obtained, ashlar, flagstone and as a source of silica for ferrosilicon and glass.

Western provinces. *Limestone.* From east to west through the southern half of Manitoba rocks of the following geologic ages are represented: Precambrian, Ordovician, Silurian, Devonian and Cretaceous. Limestones of commercial importance occur in the three middle periods and range from magnesian limestone through dolomite to high-calcium limestones.[2,16] Although building stone does not account for a large percentage of total limestone produced, the best known of the Manitoba limestones is Tyndall Stone, a mottled dolomitic limestone often referred to as "tapestry" stone. It is widely accepted as an attractive building stone, and is quarried at Garson, Manitoba, about 30 miles northeast of Winnipeg.

Limestone from Moosehorn, 100 miles northwest of Winnipeg, and from Mafeking, 25 miles east of the Saskatchewan border and 100 miles south of The Pas, is transported to Manitoba and Saskatchewan centres for use in the metallurgical, chemical, agricultural and construction industries. Limestone from Steep Rock and from Lily Bay is used by cement manufacturers in Winnipeg, and limestone from Faulkner is now being used by the lime plant at Spearhill. The possibility of utilizing marl, an unconsolidated calcareous material, from deposits in the Sturgeon Lake region of Saskatchewan in the pulp, and paper, cement, and lime industries has been investigated. Marl from a deposit 40 miles north of Edmonton is being used as raw material in cement manufacture.[6,7]

The eastern ranges of the Rocky Mountains contain limestone spanning the geologic ages from Cambrian to Triassic, with major deposits in the Devonian and Carboniferous periods in which a wide variety of types occur.[17] In southwestern Alberta high-calcium limestone is mined at Exshaw, Kananaskis and Crownsnest, chiefly for the production of cement and lime, for metallurgical and chemical uses, and for use as a crushed stone. Similar uses are made of limestone quarried at Cadomin, near Jasper.[6,7]

In British Columbia, large volumes of limestone are mined each year for cement and lime manufacture, for use by the pulp and paper industry and for various construction applications.[6,7] A large amount is exported to the northwestern United States for cement and lime manufacture. Four companies mined limestone on Texada Island, with the entire output being

Table 8. Canada, stone exports and imports, 1974-76

	1974		1975		1976^p	
	(tonnes)	($)	(tonnes)	($)	(tonnes)	($)
Exports						
Building stone, rough	11 623	777 000	11 609	974 000	10 349	1 013 000
Crushed limestone, limestone refuse	1 219 172	2 254 000	1 217 564	2 417 000	1 287 976	2 733 000
Stone crude, nes	467 072	1 502 000	288 898	976 000	559 125	1 574 000
Natural stone, basic products	. .	1 370 000	. .	1 792 000	. .	1 908 000
Total	1 697 867	5 903 000	1 518 071	6 159 000	1 857 450	7 228 000
Imports						
Building stone, rough	13 268	749 000	18 891	953 000	16 231	937 000
Crushed limestone, limestone refuse	2 525 190	5 161 000	3 281 801	6 963 000	3 513 824	7 381 000
Crushed stone including stone refuse, nes	91 193	2 796 000	84 613	3 537 000	507 860	3 143 000
Stone crude, nes	1 792	133 000	2 038	163 000	5 960	336 000
Granite, rough	13 082	958 000	28 525	1 449 000	19 167	922 000
Marble, rough	9 053	1 363 000	5 964	899 000	9 095	1 247 000
Shaped or dressed granite	. .	1 721 000	. .	1 375 000	. .	1 912 000
Shaped or dressed marble	. .	1 241 000	. .	1 885 000	. .	1 701 000
Natural stone basic products	. .	646 000	. .	584 000	. .	696 000
Total	2 653 578	14 768 000	3 421 832	17 808 000	4 072 137	18 275 000

Source: Statistics Canada.
^{p} Preliminary; . . Not available; nes: Not elsewhere specified.

Table 9. Value of construction in Canada, 1975-77

	1975[1]	1976[2]	1977[3]	Change 1976-77
	(millions of dollars)			(%)
Building construction				
Residential	8 689	11 578	11 863	2.5
Industrial	1 510	1 455	1 502	3.2
Commercial	3 732	3 328	3 257	−2.1
Institutional	1 561	1 511	1 565	3.6
Other building	1 117	1 162	1 277	9.9
Total	16 609	19 034	19 464	2.3
Engineering construction				
Marine	181	170	222	30.6
Highways, aerodromes	2 382	2 614	2 736	4.7
Waterworks, sewage systems	1 241	1 316	1 509	14.7
Dams, irrigation	138	113	128	13.3
Electric power	2 825	3 098	3 861	24.6
Railway, telephones	1 099	1 192	1 269	6.5
Gas and oil facilities	1 850	2 334	2 943	26.1
Other engineering	2 051	1 902	2 217	16.6
Total	11 767	12 739	14 885	16.9
Total construction	28 376	31 773	34 349	8.1

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.

moved by barge to Vancouver and the State of Washington. Deposits on Aristazabal Island have recently been developed for the export market. Other operations at Terrace, Clinton, Westwold, Popkum, Dahl Lake, Doeye River and Cobble Hill produced stone for construction and filler use, and for cement manufacture.[18] Periodically, interest is revived in the possible use of travertine from a British Columbia source.

Granite. In Manitoba at Lac du Bonnet northeast of Winnipeg, a durable, red granite is quarried for building and monument use. Grey granite located east of Winnipeg near the Ontario border is a potential source of building stone.

In British Columbia a light-grey to blue-grey, even-grained granodiorite of medium texture is available from Nelson Island. An andesite has been quarried at Haddington Island, off the northeast coast of Vancouver Island, for use as a building stone.

Sandstone. Sandstone for building and ornamental uses, quarried near Banff, Alberta is hard, fine-grained, medium-grey and is referred to as "Rundal Stone".

Markets, outlook and trade

Limestones are widely distributed in Canada and generally are available in sufficient quantity and with such chemical or physical specifications that long transportation hauls are unnecessary. Limestone products are low-priced commodities and only rarely, when a market exists for a high-quality, specialized product such as white portland cement or a high-purity extender, are they beneficiated or moved long distances. Provided the specifications are met, the nearest source is usually considered, regardless of provincial or national boundaries.

Over 70 per cent of Canada's annual production of limestone is used as crushed stone. This includes about 50 per cent used as road metal (broken, screened stone for asphalt roads), about 20 per cent as concrete aggregate and about 2 per cent as railroad ballast.

Some major uses in the chemical field are: neutralization of acid waste liquors, extraction of aluminum oxide from bauxite, manufacture of soda ash, calcium carbide, calcium nitrate and carbon dioxide; in pharmaceuticals, as a disinfectant, in the manufacture of dyes, rayons, paper, sugar and glass; and in the treatment of water. Dolomitic limestone is used in the production of magnesium chloride and other magnesium compounds.

Limestone is used in the metallurgical industries as a fluxing material where it combines with impurities in ore to form a fluid slag that can be separated from molten metal. Calcium limestones are used in open-

Table 10. Canada, value of construction work performed by principal type of construction, by industry, 1974-77

Industry	1974[1]			1975[1]			1976[2]			1977[3]		
	Building	Engineering	Total	Building	Engineering	Total	Building	Engineering	Total	Building	Engineering	Total
	(millions of dollars)											
Agriculture & fishing	393	212	605	435	235	670	461	249	710	500	270	770
Forestry	26	108	134	20	104	124	16	117	133	19	132	151
Mining, quarrying, oil wells	264	1 553	1 817	318	1 952	2 270	300	2 382	2 682	297	2 898	3 195
Construction	81	1	82	98	1	99	110	2	112	119	2	121
Manufacturing	1 184	586	1 770	1 175	776	1 951	1 115	752	1 867	1 162	967	2 129
Utilities	430	3 343	3 773	594	4 507	5 101	560	4 823	5 383	695	5 811	6 506
Trade	468	14	482	429	20	449	423	25	448	443	18	461
Finance, insurance, real estate	1 314	112	1 426	1 544	110	1 654	1 441	125	1 566	1 482	139	1 621
Commercial services	489	4	493	892	5	897	629	4	633	335	4	339
Housing	8 461	—	8 461	8 690	—	8 690	11 578	—	11 578	11 863	—	11 863
Institutional services	1 207	11	1 218	1 334	20	1 354	1 278	17	1 295	1 289	14	1 303
Government departments	928	3 504	4 432	1 080	4 037	5 117	1 123	4 243	5 366	1 260	4 630	5 890
Total	15 245	9 448	24 693	16 609	11 767	28 376	19 034	12 739	31 773	19 464	14 885	34 349

Source: Statistics Canada.
[1]Actual; [2]Preliminary; [3]Forecast.
— Nil.

hearth steel manufacture, whereas both calcium limestones and dolomitic limestones are used as a flux in the production of pig iron in blast furnaces.

Limestone is used extensively as a filler or an extender and, where quality permits, as whiting. In such applications both physical and chemical properties are important. Specifications vary widely but, in general, a uniform, white material passing 325 mesh would meet the physical requirements. Whiting is used in ceramic bodies, plastics, floor coverings, insecticides, paper, wood putty, rubber, paints and as a filler in many other commodities. In paint manufacture the material may be used as a pigment extender.

Agricultural limestone is used to control soil acidity and to add calcium and magnesium to the soil. Limestone and lime are used as soil stabilizers, particularly on highway construction projects.

Dolomite is the source of magnesium metal produced at Haley, Ontario; the company also uses a high-calcium lime from southeastern Ontario in the production of calcium metal. Dead-burned dolomitic limestone for use as a refractory is produced at Dundas, Ontario, by Steetley of Canada (Holdings) Limited.

Limestone from deposits in coastal areas of British Columbia is mined, crushed, loaded on barges of up to 20 000 tonnes capacity, and transported as much as 400 miles to consuming centres along the west coast in both Canada and the United States. One Canadian company, Domtar Chemicals Limited, manufactures lime at Tacoma, Washington, using limestone from Texada Island.

Crushed stone will continue to compete with sand and gravel for major markets where the latter are scarce. Through vertical integration, large operations based on construction materials can, by mergers and acquisitions, obtain captive markets for their products in operating construction firms. Construction firms can also integrate backwards into the resource field.

The possibility of substitutes for aggregates is not likely to occur soon in Canada, although in countries where such resources are scarce other materials such as compressed garbage are being used. The use of lime or cement to stabilize soils could reduce the amount of aggregate fill required on some highway or railway projects.

Traditional markets for building stone have been lost to competitive building materials such as steel and concrete. Modern design and construction methods favour the flexibility offered by use of steel and precast or cast-in-place concrete. For aesthetic qualities not available in other materials, rough or polished stone is used in many modern structures. Monumental stone continues to be in demand.

The present structure of the building stone industry in Canada is unlikely to change very soon. Recent efforts have been made on behalf of the industry to illustrate to contractors and architects the availability of a wide range of Canadian building stones and their adaptability in modern building design.

There is justifiable concern for the future development, operation and rehabilitation of pits and quarries in all locations, especially in and near areas of urban development. Rehabilitation of stone quarries for subsequent land use is generally more difficult and costly than rehabilitation of gravel pits.

Although an open-pit mining operation close to residential areas is seldom desirable, nonrenewable mineral resources must be fully and wisely utilized. Where urban sprawl has been unexpectedly rapid conflicts for land use can materialize and potential sources of raw mineral materials for the construction industry can be overrun. Master plans for land use are required to co-ordinate all phases of development so that mineral exploitation is part of the urban growth pattern.

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Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
29635-1	Limestone, not further processed than crushed or screened	free	free	25	free
30500-1	Flagstone, sandstone and all building stone, not hammered, sawn or chiselled	free	free	20	free
30505-1	Marble, rough, not hammered or chiselled	10	10	20	free
30510-1	Granite, rough, not hammered or chiselled	free	free	20	free
30515-1	Marble, sawn or sand rubbed, not polished	free	10	35	free
	General Agreement on Tariffs and Trade		5		
30520-1	Granite, sawn	free	7½	35	free
30525-1	Paving blocks of stone	free	7½	35	free
30530-1	Flagstone and building stone, other than marble or granite, sawn on not more than two sides	free	7½	35	free
30605-1	Building stone, other than marble or granite, sawn on more than two sides but not sawn on more than four sides	5	7½	10	5
30610-1	Building stone, other than marble or granite planed, turned, cut or further manufactured than sawn on four sides	7½	12½	15	7½
30615-1	Marble, not further manufactured than sawn, when imported by manufacturers of tombstones to be used exclusively in the manufacture of such articles, in their own factories	free	15	20	free
	General Agreement on Tariffs and Trade		free		
30700-1	Marble, n.o.p.	17½	17½	40	11½
30705-1	Manufacturers of marble, n.o.p.	17½	17½	40	11½
30710-1	Granite, n.o.p.	17½	17½	40	11½
30715-1	Manufacturers of granite, n.o.p.	17½	17½	40	11½
30800-1	Manufacturers of stone, n.o.p.	17½	17½	35	11½
30900-1	Roofing slate, per square of 100 square feet	free	free	75¢	free

30905-1	Granules, whether or not coloured or coated, for use in manufacture of roofing, including shingles and siding	free	free	25	free

United States

Item No.		
513.21	Marble chips and crushed	5
513.61	Granite, not manufactured, and not suitable for use as monumental, paving or building stone	free
514.11	Limestone, crude, not suitable for use as monumental, paving or building stone, per short ton	10¢
514.91	Quartzite, whether or not manufactured	free
515.11	Roofing slate	12.5
515.14	Other slate	5
515.41	Stone, other, not manufactured and not suitable for use as monumental, paving or building stone	free

Sources: For Canada, the Custom Tariff and Amendments, Department of National Revenue, Customs and Excise Division. For United States, Tariff Schedules of the United States, Annotated (1976) T.C. Publication 749.
Note: Varying tariffs are in effect on the more fabricated stone categories.
n.o.p. Not otherwise provided for.

Sulphur

G.H.K. PEARSE

Sulphur, one of the most important and versatile industrial raw materials, is widely distributed throughout the world in both elemental and combined forms. It has been used by man since antiquity and today is used at some stage in the production of almost everything we eat, wear or use. More than half of the world's sulphur output is in elemental form, nearly all obtained from native sulphur deposits and sour natural gas. The remainder is recovered from pyrite and smelter stack gases, principally as sulphuric acid, in which form 87 per cent of all sulphur is consumed. Fertilizer manufacture accounts for about half of all sulphur consumed, followed by chemicals, pigments, and pulp and paper as the next-largest consuming sectors.

World sulphur production in all forms at 51.8 million tonnes* in 1976 is little changed from the previous two years and in fact is below that of 1974. A 4.5 per cent increase in production in communist countries was offset by a decline in that of the Western World. World consumption, on the other hand rose 3.5 per cent to 46.7 million tonnes. This remains below the peak 1974 consumption of 48.4 million tonnes.

Canada's total elemental sulphur sales in 1976, at 3.8 million tonnes, were 7.3 per cent less than in 1975, more than 1 million tonnes below the peak of 1974. Sulphur stockpiles on the prairies were 18.5 million tonnes at year-end.

The Canadian sulphur industry

Canadian sulphur is obtained from three sources: elemental sulphur derived from sour natural gas and petroleum, sulphur recovered from smelter gases in the form of sulphuric acid, and sulphur contained in pyrite concentrates used in sulphuric acid manufacture. Minor tonnages of elemental sulphur are recovered as a byproduct of electrolytic refining of nickel sulphide matte, and a small quantity of liquid sulphur dioxide is produced from pyrites and smelter gases. In 1976, 82.6 per cent of Canadian sulphur shipments were in elemental form, nearly all from sour natural gas in western Canada. Canada has been the world's largest exporter of elemental sulphur since 1968.

Canadian elemental sulphur production from sour natural gas declined for the third consecutive year.

Hydrocarbon sources

Hydrocarbons contain sulphur in some form in at least minute amounts. Where the sulphur content is unacceptably high, as it is in many gas reservoirs in western Canada, it must be removed. Hydrogen sulphide (H_2S), the dominant sulphur compound occurring in sour natural gas, is presently the most important source of sulphur in Canada. Because of the need to strip highly corrosive and toxic hydrogen sulphide from gas prior to marketing, the elemental sulphur produced is an involuntary byproduct of natural gas operations.

Sulphur recovery in Canada from Athabasca oil sands and crude oil is comparatively minor at present, and from coal is virtually nil. However, with ever-increasing energy requirements, and with stringent air pollution regulations coming into force, these vast sources of sulphur will, in the future, contribute substantially to world supply.

Sour natural gas

Although the H_2S content of sour gas fields ranges as high as 91 per cent by weight of the total raw gas in place, most of the producing fields contain from 1 to 20 per cent. The modified Claus process in one of its variants is used to recover sulphur from sour natural gas. Briefly, the method is as follows: H_2S is extracted by absorption into a solution of one of diethanolamine, monoethanolamine, hot potassium carbonate, or sulfinol. The solution is then heated in a stripper tower where H_2S is evolved. The H_2S passes into a furnace where a controlled air flow results in partial oxidation of H_2S to permit these reactions:

$$2H_2S + 3O_2 \lesseqgtr 2H_2O + 2SO_2$$

$$2H_2S + SO_2 \lesseqgtr 2H_2O + 3S$$

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Gas from this furnace enters a condenser-converter series and a portion of liquid sulphur is removed from the vapour in each unit. Overflow gases then pass through another reaction furnace and the process is repeated until 95 per cent or more of the original sulphur has been removed. In the case of large plants the tail gases are passed through a cleanup unit to increase recovery efficiency. Liquid sulphur is fed into

Table 1. Canada, sulphur production and trade 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production				
Pyrite and pyrrhotite[1]				
Gross weight	21 120	. .	31 000	. .
Sulphur content	10 560	127 271	16 000	240 000
Sulphur in smelter gases[2]	694 666	9 640 642	781 000	15 454 000
Elemental sulphur[3]	4 078 780	91 847 393	3 781 000	63 339 000
Total sulphur content	4 784 006	101 615 306	4 578 000	79 033 000
Imports				
Sulphur crude or refined				
United States	14 335	911 000	15 717	1 111 000
Total	14 335	911 000	15 717	1 111 000
Exports				
Sulphur in ores (pyrite)				
United States	. .	170 000	. .	152 000
Total	. .	170 000	. .	152 000
Sulphuric acid and oleum (contained sulphur)				
United States	225 382	4 324 000	349 804	6 872 000
Other countries	20	4 000	22	8 000
Total	225 402	4 328 000	349 826	6 880 000
Sulphur crude or refined, nes				
United States	974 760	22 739 000	1 011 423	18 647 000
South Africa	187 385	8 752 000	292 367	11 008 000
Australia	258 386	9 813 000	224 797	9 066 000
India	121 843	5 392 000	214 982	7 599 000
Brazil	119 300	3 289 000	270 370	7 535 000
Netherlands	172 927	6 565 000	214 855	6 839 000
New Zealand	106 002	4 537 000	152 682	6 151 000
Taiwan	194 974	5 738 000	150 137	6 078 000
France	96 969	4 531 000	132 809	5 809 000
Italy	338 792	10 447 000	243 259	5 131 000
Tunisia	40 135	2 303 000	137 473	5 004 000
Belgium and Luxembourg	202 535	10 199 000	155 578	4 862 000
South Korea	112 788	4 793 000	77 484	3 260 000
Argentina	29 434	1 835 000	74 252	2 623 000
Other countries	328 016	12 103 000	367 524	10 281 000
Total	3 284 246	113 036 000	3 719 992	109 893 000

Sources: Statistics Canada. Department of Energy, Mines and Resources, Ottawa.
[1]Producers' shipments of byproduct pyrite and pyrrhotite from the processing of metallic sulphide ores. [2]Sulphur in liquid SO_2 and H_2SO_4 recovered from the smelting of metallic sulphides and from the roasting of zinc-sulphide concentrates. [3]Producers' shipments of elemental sulphur produced from natural gas; also included are small quantities of sulphur produced in the refining of domestic crude oil and from the treatment of nickel-sulphide matte.
pPreliminary; . . Not available; nes Not elsewhere specified.

an underground storage pit for pumping to outside storage blocks where the liquid cools and solidifies, or to liquid storage tanks for direct shipping to North American markets in liquid form. Alternatively, the liquid is fed into a slating plant where it is quenched in water on a special belt, subsequently breaking up into "slates"; or to a milling plant.

A variety of prilling or pelletizing processes have been under investigation over a number of years and a few have been commercialized in Europe: the Sulpel and Kaltenback processes, which use water as a quenching medium; and a Polish process and the French Perlomatic process which use rising currents of air as a quenching medium. A 300-tonne-a-day Perlomatic plant was installed recently at Petrogas' Balzac, Alberta operation and the product is destined primarily for agricultural use as a soil nutrient.

Canada's first sour natural gas sulphur recovery plant came on stream in Alberta in 1951, and sulphur output in 1952 was 8 000 tonnes. In 1976, 45 plants were operating, including one in Saskatchewan and two in British Columbia with a combined daily capacity of 26 286 tonnes, up slightly from the previous year as a result of minor expansions to several existing plants and an addition to Sun Oil Company Limited's 83-tonne-a-day Rosevear, Alberta plant. Production of elemental sulphur from natural gas in Alberta, as reported by the Alberta Energy Resources Conservation Board, was 6 177 067 tonnes in 1976, a decrease of 4 per cent from that of 1975. Production in 1976 in British Columbia was 61 400 tonnes, and in Saskatchewan 3 000 tonnes. Total Canadian production for 1976 was 6 241 467 tonnes of elemental sulphur derived from sour gas.

Alberta sulphur sales were 3 918 948 tonnes in 1976, up 4 per cent from 1975. Reflecting a decline in prices, the value of sales decreased 23 per cent to just over $66 million in 1976. Alberta inventories stood at 18 482 753 tonnes at December 31, 1976. In 1976 British Columbia and Saskatchewan elemental sulphur sales were 25 327 tonnes and 3 000 tonnes, and inventories were 174 523 tonnes and 5 700 tonnes, respectively.

Canadian elemental sulphur productive capacity, having doubled between 1968 and 1972, reached a plateau in 1973 from which output declined for the third consecutive year. Although Shell Canada Limited's sour gas discovery in the Rosevear area during 1975 may prove to be substantial, if so, it would be the first important find since the late 1960s. With a lag of three to four years between discovery and plant start-up, a significant increment in sulphur capacity cannot be expected before 1979. The only additional capacity scheduled for 1977 is the expansion of Shell Canada Resources Limited's Burnt Timber plant which will double sulphur capacity to 374 tonnes a day.

Pollution abatement guidelines for natural gas plants laid down in November 1971 by the Alberta government include: mandatory stack clean-up facilities and recovery efficiencies between 97 and 99 per cent, depending on acid gas quality, for plants rating over 1 000 tons a day; minimal stack clean-up or equipment with efficiency between 94 and 98 per cent for plants rated between 400 and 1 000 tons a day; at least a three-stage Claus unit or equivalent, with efficiency between 92 and 96 per cent for 100-to 400-ton plants; and a two-stage Claus unit with recovery efficiency between 90 and 94 per cent for smaller plants. As of December 31, 1976 all Alberta plants must comply with this requirement.

Prior to 1974, all sulphur destined for offshore markets was railed to loading terminals at Vancouver, some 650 miles from processing plants. During the last three years sulphur has been shipped via Churchill, Manitoba; Thunder Bay, Ontario and Quebec City, Quebec. In 1976, 147 840 tonnes were moved through these alternate ports (mainly Quebec City and Thunder Bay), an increase of about 50 per cent over the levels of the previous two years. These ports could increase in importance with the recovery of markets, although Amoco Canada Petroleum Company Ltd. has ceased shipments through Churchill indefinitely.

Athabasca oil sands

The Athabasca oil sands constitute a vast deposit of relatively unconsolidated sandstone impregnated with bitumen, covering some 30 000 square miles of north-eastern Alberta. The estimated 300 billion barrels of recoverable oil in the formation contain about 2 billion tonnes of sulphur.

In late 1967 Great Canadian Oil Sands Limited (GCOS) completed the first commercial oil-sand extraction plant at a cost of $240 million. The ancillary sulphur recovery plant is designed to produce 300 tonnes of sulphur daily. Sulphur production was 101 979 tons in 1976, up 18 per cent from the previous year. A new sulphur plant with a capacity of 390 tonnes a day is scheduled for construction in 1977.

Shipments from GCOS began in October 1974 from Quebec City, destined for offshore markets, and reached 81 000 tonnes in 1976. Another project, that of Syncrude Canada Ltd., is under construction and is expected to be completed in 1978. It is designed to produce 125 000 b/d of synthetic crude oil and products and, when fully geared up in 1980, the total annual sulphur capacity from the tar sands will be some 400 000 tonnes. Beyond this, it appears that two other projects originally scheduled for completion in the early 1980s, those of the Petrofina Canada Ltd. group and Shell Canada Limited, will now not likely come on stream before 1985, if at all. The 2 million tonnes a year of sulphur from the tar sands forecast a few years ago for 1985 now seems an optimistic figure for the year 2000.

Oil refineries

Some crude oils contain as much as 5 per cent sulphur, either as hydrogen sulphide or in other compounds.

Table 2. Canada, sour gas sulphur extraction plants, 1976

Operating Company	Source Field or Plant Location	H_2S in Raw Gas	Daily Capacity
	(Alberta, except where noted)	(%)	(long tons)
Amerada Hess Corporation	Olds	11	383
Amoco Canada Petroleum	Bigstone Creek	19	394
Amoco Canada Petroleum	East Crossfield	34	1 800
Aquitaine Company of Canada	Rainbow Lake	4	140
Aquitaine Company of Canada	Ram River	9-35	4 508
Atlantic Richfield	Gold Creek		42
Saratoga Processing Company	Savannah Creek (Coleman)	13	399
Canadian Occidental	Taylor Flats, B.C.	3	325
Canadian Superior Oil	Harmattan-Elkton	53	482
Canadian Superior Oil	Lonepine Creek	12	151
CanDel Oil	Minnehik-Buck Lake		32
Chevron Standard	Kaybob South	19	3 465
Chevron Standard	Nevis	7	258
Gulf Oil Canada	Nevis	3-7	290
Gulf Oil Canada	Pincher Creek	10	196
Gulf Oil Canada	Rimbey	1-3	347
Gulf Oil Canada	Strachan	10	955
Home Oil	Carstairs	1	79
Hudson's Bay Oil and Gas	Brazeau River	1	90
Hudson's Bay Oil and Gas	Caroline	1	24
Hudson's Bay Oil and Gas	Edson	2	285
Hudson's Bay Oil and Gas	Hespero (Sylvan Lake)	1	17
Hudson's Bay Oil and Gas	Kaybob South (1)	17	1 070
Hudson's Bay Oil and Gas	Kaybob South (2)	17	1 020
Hudson's Bay Oil and Gas	Lonepine Creek	10	279
Hudson's Bay Oil and Gas	Sturgeon Lake South	10	96
Imperial Oil	Joffre		18
Imperial Oil	Quirk Creek		302
Imperial Oil	Redwater	3	34
Mobil Oil Canada	Wimborne	14	358
Petrofina Canada	Wildcat Hills	4	174
Petrogas Processing	Crossfield (Balzac)	31	1 700
Shell Canada	Burnt Timber Creek	8-5	187
Shell Canada	Innisfail	14	158
Shell Canada	Jumping Pound	3-5	530
Shell Canada	Simonette River	15	209
Shell Canada	Waterton	18-25	2 976
Steelman Gas	Steelman, Sask.	1	7
Sun Oil	Roseevear		83
Texaco Exploration	Bonnie Glen		13
CDC Oil & Gas Limited	Nordegg		45
Texasgulf Inc.	Okotoks	33	452
Texasgulf Inc.	Windfall	16	1 220
Westcoast Transmission	Fort Nelson, B.C.		250
Western Decalta	Turner Valley	4	10
Total daily rated capacity — December 31, 1976			26 286

Source: From a compilation by *Oilweek*.

Domestic crudes generally contain less than 1 per cent sulphur. The sulphur may either be removed in the form of H_2S, or treated to form nondeleterious disulphides. Recovery techniques employed during oil refining are similar to those used in the removal of sulphur from sour gas.

In Canada, sulphur is recovered from imported crudes at oil refineries in Nova Scotia, New Brunswick, Newfoundland and Quebec, and from domestic crudes at oil refineries near Toronto, Sarnia, Winnipeg, Edmonton and Vancouver. Total sulphur output from refineries in 1976 was an estimated 160 000 tonnes, including 60 000 tonnes from Montreal refineries alone. This recovery represents only 20 per cent of total sulphur contained in the crude.

Coal and oil shales

Coke oven gases generally contain some hydrogen sulphide, the quantity dependent upon the sulphur content of the coal being carbonized. Ordinarily the H_2S is removed in "iron oxide boxes", but it can also be recovered and converted to elemental sulphur.

In response to the demand for increasing amounts of clean fuel, numerous research projects were initiated over the last few years with the aim of developing high quality, pollution-free gas from coal. Escalation of the energy crisis, particularly in the United States and Europe, brought about by Middle East oil supply cutbacks near the end of 1973, has given further impetus to gasification projects and oil shale studies. Annual sulphur recovery from these sources, largely in the United States, could reach 1 million tons by 1990 and 5 million tons by the end of this century. Although coal in western Canada is low in sulphur (less than 0.5%), coal from the Maritimes is notably sulphurous. With more stringent pollution regulations coming into force, coal gasification may become the only way in which this energy source can be utilized in the future.

Table 3. Proposed expansions for 1977

Operating Company	Location	Proposed Daily Rated Capacity (tons)
Shell Canada Limited	Burnt Timber	374 (187[1])

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]present capacity in brackets.

Metallic sulphide sources

In Canada the use of metallic sulphides for their sulphur content dates back to 1866. Early operations consisted essentially of roasting pyrite for the direct manufacture of sulphuric acid. In the 1920s the use of base-metal smelter gases for the manufacture of byproduct H_2SO_4 began near Sudbury, Ontario, and at Trail, British Columbia. Virtually all Canada's sulphur production was from metallic sulphides prior to 1951 when the first sour gas sulphur recovery plant was built. In 1976 metallic sulphides, including smelter gas sulphur, provided an estimated 780,000 tonnes of contained sulphur.

Smelter gases

Effluent gas from smelting of sulphide ores contains from 1 to 12 per cent sulphur dioxide (SO_2). Recovery of SO_2 includes processes for cleaning, purifying, cooling and concentrating. Concentrated SO_2 is then used directly for the manufacture of H_2SO_4 via the contact-acid process. As much as 170 000 tonnes (85 000 tonnes sulphur content) of SO_2 is produced for use as a processing agent in a variety of applications. Some SO_2 is used for the manufacture of oleum (fuming sulphuric acid, $H_2S_2O_7$). Production in 1976 was 781 000 tonnes of sulphur contained in smelter gases, up 12 per cent from the previous year. Proposed increments to smelter capacity and increased sulphur recovery efficiency presages a rapid growth in sulphuric acid output over the next ten years.

The largest sulphuric acid plant complex in Canada is that of Canadian Industries Limited (CIL) at Copper Cliff, Ontario. The company operates three acid plants that have a combined annual capacity of 900 000 tonnes of H_2SO_4 based on SO_2 gas from Inco Limited's iron ore recovery plant. In addition, CIL has a liquid sulphur dioxide plant at Inco's nearby Copper Cliff smelter. Much of the acid produced at Copper Cliff is shipped by unit-train about 475 miles to CIL's fertilizer works near Sarnia, Ontario. The company owns a sulphuric acid depot at Niagara Falls, Ontario, which consists of a 60 000-short-ton storage tank and equipment for unloading unit-trains and loading tank cars and trucks. Acid from Copper Cliff is shipped directly to the facility via 56-car unit-trains.

Subsidiaries of Noranda Mines Limited produce smelter acid at three localities: Gaspé Copper Mines, Limited's 245 000 tonne-a-year plant at Murdochville, Quebec, Brunswick Mining and Smelting Corporation Limited's 125 000-tonne-a-year plant at Belledune, New Brunswick and Canadian Electrolytic Zinc Limited's zinc concentrate roasting facility at Valleyfield, Quebec with a capacity of 120 000 tonnes a year. A proposed new copper smelter and associated 100 000-tonne-a-year sulphuric acid installation to be built at Noranda, Quebec has been shelved for the time being.

Cominco Ltd's sulphuric acid capacity at Trail, British Columbia, based on its lead-zinc smelter, was increased 30 per cent in 1975 to 490 000 tonnes a year with the replacement of the older units by a single plant. Acid capacity at the company's Kimberley plant is 300 000 tonnes a year. Much of the acid produced is utilized by Cominco in the manufacture of fertilizers.

Allied Chemical Canada, Ltd. produces sulphuric acid from the roasting of zinc concentrates supplied under agreement with Canadian Electrolytic Zinc, whereby Allied retains the acid for its own use and delivers the zinc calcine to Canadian Electrolytic Zinc's nearby refinery.

Texasgulf Canada Ltd.'s Timmins, Ontario zinc plant has a sulphuric acid capacity of 200 000 tonnes a year. An expansion plan will raise acid output to 400 000 tonnes by 1978. A second stage, now deferred, was to have raised capacity to 560 000 tonnes by 1979. A proposed associated phosphate fertilizer works has been shelved.

Falconbridge Nickel Mines Limited has announced plans for the replacement of its blast furnaces with electric melting equipment and installation of fluid-bed roasters.

Shipments of acid and oleum to the United States in 1975 were 349 804 tonnes of contained sulphur. Small amounts were shipped elsewhere, mainly to the West Indies.

Pyrite and pyrrhotite

Pyrite and pyrrhotite concentrates produced as a byproduct of base metal mining operation are sometimes marketed for their sulphur content. A distinction is made in this review between this category of sulphur in pyrite / pyrrhotite and that in smelter gases. For example, although most of the acid production at Copper Cliff, Ontario is dependent upon the roasting of iron sulphides, the sulphur production is reported as smelter gases. In other instances, however, the iron sulphide concentrates are sold and shipped for roasting elsewhere and are reported as pyrite and pyrrhotite production.

Noranda Mines Limited and Normetal Mines Limited have, over the years, shipped pyrite to acid plants, principally in the northeastern United States. Conversion to elemental sulphur feed at acid plants resulted in a drastic reduction in pyrite usage. Noranda discontinued pyrite sales in 1973. In 1976, Canada's pyrite and pyrrhotite shipments amounted to an estimated 31 000 tonnes of concentrates (16 000 tonnes contained sulphur).

Canada consumption and trade

In 1976 Canadian consumption of sulphur in all forms, as reported by consumers, amounted to about 1.4 million tonnes.

Canada remains the largest exporter of elemental sulphur, having shipped 3 719 992 million tonnes in 1976.

Byproduct sulphur from western Canada has over the years penetrated much of the United States market. From the outset this country has been the principal destination for Canadian sulphur and presently accounts for about 30 per cent of Canadian exports. Sales to the United States were up 7 per cent from 1975. Shipments to Europe, which had almost quadrupled between 1971 and 1974 largely as a result of major increases in Dutch, British and Italian purchases, were down 9 per cent in 1976 at an esti-

Table 4. Canada, principal sulphur operations based on metallic sulphides, 1974

Operating Company	Plant Location	Raw Material	Annual Capacity 100% H_2SO_4	Annual Capacity Approx. S. equiv.
			(tonnes)	
Smelter gases				
Brunswick Mining and Smelting	Belledune, N.B.	SO_2 lead-zinc	125 000	42 000
Allied Chemical	Valleyfield, Que.	SO_2 zinc conc.	140 000	47 000
Canadian Electrolytic Zinc	Valleyfield, Que.	SO_2 zinc conc.	120 000	40 000
Canadian Industries[1]	Copper Cliff, Ont.	SO_2 pyrrhotite	900 000	300 000
Cominco[1]	Trail, B.C.	SO_2 lead-zinc	435 000	145 000
	Kimberley, B.C.	SO_2 pyrrhotite	275 000	92 000
Texasgulf Canada Ltd.	Timmins, Ont.	SO_2 zinc conc.	205 000	70 000
Gaspe Copper Mines	Murdochville, Que.	SO_2 copper	245 000	82 000
		TOTAL	2 435 000	895 000
Pyrite and pyrrhotite				
Noranda Mines	Noranda, Que.	Sulphide ore	Pyrite concentrate[2]	
Normetal Mines Limited	Normetal, Que.	Sulphide ore	Pyrite concentrate[2]	

Sources: Company data.
[1]Does not include 85 000 tons sulphur content in liquid SO_2 production. [2]Currently inactive.

Table 5. Canada, sulphur production and trade, 1965, 1970, 1974-76

	Production				Imports	Exports	
	Pyrites[1]	In Smelter Gases	Elemental Sulphur	Total	Elemental Sulphur	Pyrites	Elemental Sulphur
			(tonnes)			($)[2]	(tonnes)
1965	169 597	403 452	1 876 295	2 449 344	147 137	978 828	1 358 828
1970	159 222	640 319	3 218 766	4 018 307	48 491	1 226 000	2 710 886
1974	24 475	663 321	5 033 057	5 720 853	31 389	648 000	4 251 487^r
1975	10 560	694 666	4 078 780	4 784 006	14 335	170 000	3 284 246^r
1976^p	16 000	781 000	3 781 000	4 578 000	15 717	152 000	3 719 992

Source: Statistics Canada.
[1]See footnotes for Table 1. [2]Dollar value of pyrite exports quantities not available.
^p Preliminary; ^r Revised.

mated 840 000 tonnes. Asian sales declined 6.5 per cent in 1976 to 514 000 tonnes following a 26 per cent decrease in 1975, essentially as a result of greatly reduced sales to Taiwan and South Korea. Although Australasia's Canadian purchases were 6 per cent greater in 1976 at 371 000 tonnes, this was well below the peak 685 000 tonnes recorded in 1974.

On the other hand, sales to South America and Africa (principally Brazil and the Republic of South Africa) each rose to new peaks, exceeding 450 000 tonnes. Together, these continents accounted for 27 per cent of total Canadian exports.

World review

World sulphur production in 1976 was little changed from the previous year and remained below that of 1974 as a result of reduced output from both voluntary and involuntary byproduct operations in the western world. The cutbacks were, in part, in response to reduced demand but more permanent constraints to production among several major world suppliers have become manifest over the past few years. The effects of exhaustion of reserves, limited exploration success and prohibitive energy costs in established producing areas have been further magnified by slower than anticipated developments in new source areas.

After almost two years of slack demand affecting virtually all manufacturing sectors, signs of at least a moderate recovery during the last half of 1976 were indicated by improving sulphur markets. The fertilizer sector, which accounts for over half of sulphur consumption, was depressed by buyer resistance to substantial increases in phosphate fertilizer prices posted during 1975 and by weather conditions unfavorable to fertilizer consumption in 1976. The resulting high inventory levels further extended the recession in this industry, although signs of improvement were evident in the closing months of the year. In summary, world sulphur consumption increased 3.5 per cent over that of 1975 but remained below that of the boom year 1974.

The world's largest producer of sulphur in all forms is the United States, with the majority of production derived from Frasch mines in the Gulf Coast area. Development of the Frasch mining technique in 1895 made large tonnages of low-cost sulphur available to world markets and established the United States as the world's foremost supplier of elemental sulphur. In 1976 Frasch production fell for the second consecutive year, dropping to 6.26 million tonnes, the lowest output since 1965. Recovered elemental sulphur, principally from sour natural gas, increased 5 per cent to 3.11 million tonnes. Shipments of elemental sulphur at 8.97 million tonnes were unchanged from that of 1975 and stocks increased by 440 000 tonnes to 5.30 million tonnes. Exports in 1976 at 1.18 million tonnes were 9 per cent below that of the previous year. Imports decreased 11 per cent to 1.7 million tonnes and domestic consumption declined a marginal 1 per cent to 9.5 million tonnes, although strong growth was evident in both these categories during the last few months of the year. Texasgulf Inc.'s Spindletop mine closed in early 1976, and early in 1977 the company's Fannett mine closed. Reserve depletion and high costs were cited as the reasons.

Mexican elemental sulphur production decreased marginally in 1976 to 2.0 million tonnes. Domestic shipments, which have tripled in six years in response to growth in the fertilizer industry, were an estimated 750 000 tonnes in 1976. As a result of depressed markets and reported production problems, Mexico's exports declined 25 per cent to 1.05 million tonnes. This figure is 45 per cent less than that for the peak year, 1974.

Production of elemental sulphur from sour natural gas from the Lacq field in France in 1976 was 1.7 million tonnes, a production plateau reached in 1969. Exports increased by 20 per cent to 0.68 million tonnes in 1976, still well below the annual 1-million-tonne level maintained for many years.

Elemental sulphur output from sour gas in northern West Germany decreased 7 per cent to 520 thou-

Table 6. Canadian export markets for sulphur, 1976

Country or Area	Exports	Per cent of Total
	(million tonnes)	
United States	1.01	27.2
Europe	.86	23.1
South Africa	.29	7.8
Brazil	.27	7.3
Italy	.24	6.4
Australia	.22	5.9
India	.21	5.7
New Zealand	.15	4.0
Others	.47	12.6
Total	3.72	100.0

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

Table 7. Canada sulphur consumption, 1965, 1970, 1974-76

	From Pyrites and Smelter Gases[e]	Elemental Sulphur[1]	Total
		(tonnes)	
1965	445 197	670 569	1 115 766
1970	693 952	763 603	1 457 555
1974	642 096	897 155	1 539 251
1975	691 118[r]	. .	. .
1976[p]	786 867	. .	. .

Source: Statistics Canada.
[1] As reported by consumers.
[e] Estimated by Mineral Development Sector; [p] Preliminary; . . Not available; [r] Revised.

sand tonnes. This source, although generally having increased its capacity utilization over the years, has been plagued by technical problems.

Polish production increased 2 per cent over that of 1975 to 4.8 million tonnes. Exports to western markets remained stagnant at about 1.5 million tonnes; however there was an estimated 500 000-tonne increase in sales to Eastern Bloc countries.

Iraq became a significant producer of elemental sulphur in 1973. Capacity is reported to have reached 1 million tonnes a year, but no expansion to the estimated 700 000-tonne output is expected until improved rail transport capability to the Persian Gulf port of Umm Qasr, 450 miles to the south, is completed. Shipments by truck to Lebanon for Mediterranean customers was begun in 1974 and this mode will become more significant as the truck fleet is expanded through purchases from Mercedes.

Outlook

The near-term outlook for sulphur is for the resumption of demand growth, although the degree of recovery depends on the related recovery of industrial production and, in the case of fertilizers, on a host of factors including the liquidity of third world finances, agricultural aid and even the weather. Supply, on the other hand, is limited by several factors unrelated to the recession and no significant growth in output can be foreseen for several years. Availability of elemental sulphur from Canada and Iraq is constrained by transportation bottlenecks, although use of alternate ports in Canada offers modest relief. United States Frasch producers are facing rapidly escalating costs, Mexican producers are experiencing technical problems and both are concerned about dwindling reserves. France's elemental sulphur output reached a plateau several years ago. Of the major producers, only Poland appears capable of increasing output significantly, although there is a possibility that the Machow open pit will close and a decision is pending on whether or not to open a new, Frasch-type deposit under present market conditions. In balance, sulphur supplies for the next year or two will be more than adequate, even with a reduction in output.

For the longer-term, fertilizer requirements, under the stimulus of world food shortages and the expansion of modern agricultural practice in Asia, Africa and Latin America, will continue to consume a growing proportion of sulphur output. Many observers interpret growing substitution by hydrochloric and other acids in the important pigment, steel-pickling and oil-refining sectors as presaging a significant tapering-off of growth in sulphur consumption in the manufacturing sector and thus an overall moderation of sulphur consumption growth. However, an examination of the positive as well as the negative elements in the demand picture suggests that such a view may be too pessimistic. In fact, when considering substitution, sulphur's role in the manufacture of substitute reagents must be taken into account. For example, the expected switch to hydrofluoric acid in petroleum refining could result in an increase in sulphur consumption, since three tonnes of H_2SO_4 are needed to produce one tonne of HF. Also, in addition to conventional fertilizer use, attention has been drawn in recent years to sulphur's important role as a plant nutrient and to sulphur deficiencies in the soil over broad areas throughout the world. An area of growth in the "other uses" category is that of uranium production. Uranium ore leaching requires 30 to 50 tonnes of sulphuric acid per tonne of uranium in the

Table 8. Canada, consumption of elemental sulphur by industry

	1974	1975
	(tonnes)	
Fertilizers	449 481^r	
Pulp and paper	299 063^r	
Chemicals	88 314^r	
Foundry	11 253	
Rubber products	3 065	
Other industries[1]	45 979^r	
Total	897 155	

Source: Statistics Canada. Breakdown by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Includes production of artificial abrasives, aluminum, electrical apparatus, explosives, food processing, glass and glass products, paint, starch, and other minor uses.
^{r}Revised.

Table 9. Canada, sulphuric acid production, trade and apparent consumption, 1965, 1970, 74-76

	Production	Imports	Exports	Apparent Consumption
	(tonnes — 100% acid)			
1965	1 964 055	2 790	51 812	1 915 033
1970	2 475 070	9 948	129 327	2 355 691
1974	2 820 986	124 740	249 198	2 696 528
1975	2 723 202	154 020	225 402^r	2 651 820
1976^p	2 842 431	39 537	349 826	2 532 142

Source: Statistics Canada.
^{p}Preliminary; ^{r}Revised.

ore, plus additional acid required indirectly in the manufacture of hydrofluoric acid and other chemicals used in processing. Demand for sulphur contained in acid for world uranium production in 1975 was an estimated 350 000 tonnes. By the year 2000 annual requirements are expected to exceed 2 million tonnes. Ore and tailings leaching in base-metal production, and anticipated developments in hydrometallurgy, are other consuming areas with high growth potential. Several new uses for elemental sulphur based on attractive engineering properties have been under development in recent years. Although some of these are fairly sensitive to sulphur prices, uses such as sulphur-asphalt road surfacing mixtures could become important consumers of sulphur. In summary, it would appear that the historical sulphur demand growth of 4.5 per cent a year will be maintained over the medium-to long-term.

In the final analysis, sulphur supply is likely to be the most important factor in sulphur's fortunes. As one of the earth's most abundant elements, no ultimate shortage is foreseeable; however, an examination of likely rates of development from the various sources provides a less-assuring outlook.

Although Canada is the world's largest exporter of sulphur, with a 30 per cent share of total trade, its impact on world sulphur markets is expected to decline. Production of elemental sulphur from sour natural gas peaked in 1973 at 7.1 million tonnes and output in 1976 was 13 per cent less than this figure. Several of the major plants are recycling operations, i.e., sulphur is stripped from the gas and the gas returned to the reservoir. Output from these plants is now tapering off, and considering the reserve picture for the others, a reduction to about one half of the current output from existing plants is expected by 1985. Replacement of part of this lost production capability through new discoveries and reserve extensions, especially with the recent gas price increases, will occur. However, given the fact that only one significant sour gas find — that of Shell's Rosevear discovery in 1975 — has been made during the last six to seven years, and considering a lag time of three or four years between discovery and production, no major increment in output is likely before the end of the decade. Sulphur recovery from the Athabasca oil sands depends on the rate of exploitation of this source of oil. Current estimates in the order of 400 000 b/d by 1985 are less by two thirds than earlier projections. Sulphur from metallic sulphides, produced largely in the form of sulphuric acid, could double by 1985. However, it is unlikely that new sour gas discoveries and growth in output of metallurgical and oil sands sulphur will be adequate to offset the decline in Canadian production before the late 1980s.

United States Frasch producers' output declined 13 per cent in 1976 from the previous year and was 21 per cent below the high of 8.0 million tonnes in 1974. Although much of this reduction was in response to weak demand, two critical constraints are making themselves felt. Costs have more than doubled recently as a result of price increases for essential natural gas and rising labour and material costs. At best, producers will have to face the problem of continued escalating costs of production, and fuel supply cuts remain a distinct possibility. Also, notwithstanding the success of the Duval Corporation's mine in west Texas, which has a capacity of 2.4 million tonnes a year, and Texasgulf Inc.'s 500 000-ton operation which started up in 1976, there is little scope for growth in Frasch output. The closure of Freeport Minerals Company's Lake Pelto mine during 1975, Texasgulf's Spin-

Table 10. Canada, available data on consumption of sulphuric acid by industry, 1974

	(tonnes — 100% acid)
Iron and steel mills	10 832
Other iron and steel	20
Electrical products	168
Pulp and paper mills	180 235
Processing of uranium ore	73 103
Manufacture of mixed fertilizers[1]	15 385
Manufacture of plastics and synthetic resins	16 197
Manufacture of soaps and cleaning compounds	19 754
Other chemical industries	23
Manufacture of industrial chemicals[2]	1 995 487
Petroleum refining	28 581
Mining[3]	49 895[e]
Nonferrous smelting and refining	105 652
Miscellaneous[4]	17 658
Total	2 512 990

Source: Statistics Canada.
[1]Includes consumption for production of super-phosphate in this country. [2]Includes consumption of "own make" or captive acid by firms, classified to these industries. [3]Includes metal mines, nonmetal mines, mineral fuels and structural materials. [4]Includes leather tanneries, synthetic textiles, explosives and ammunition and other petroleum and coal products, mineral wool, starch and glucose, vegetable oils, sugar refining and textile drying and finishing.
[e]Estimated.

dletop mine in early-1976 and the latter company's Fannett mine in February 1977, is symptomatic of a net decline in reserves. Of 37 Frasch mines developed since the inception of the industry in 1895, only 11 remain in operation. More significantly, of 12 mines developed during the last 15 years, seven have closed down. Exploration and development to date indicate that the decline is unlikely to be arrested, and likely output by 1985 is forecast by various analysts to be between 5.5 and 6.5 million tonnes.

Although there may be scope for sulphur exploration and development in Mexico, present Frasch operations are experiencing technical difficulties in addition to cost constraints similar to those affecting United States operators. Except for the all-time high of 2.3 million tonnes in 1974, production has varied between 1.2 and 1.8 million tonnes for much of its 23-year history. Without exploration successes, significant production growth is highly unlikely.

Sulphur production from sour natural gas in France is expected to decline to 1.5 million tonnes by 1985.

Poland's Frasch production may reach 6 to 7 million tonnes and the output from newly-emerging Middle East producers — sour gas and Iraqii Frasch — will likely rise to 3.0 million tonnes by 1985. However, rapid consumption growth in the communist bloc and in the Middle East will modify the effects of these additional supplies.

Despite the fact that pollution-abatement sulphur will become mort important, its impact, for several reasons, is proving to be less dramatic than earlier predictions suggested. For sulphur removal from electric utility stack gases, the largest source of pollution-sulphur, economic and technologic considerations weigh in favour of a scrubbing process which will result in an impure gypsum waste product. Advances in acid-producing technology could result in this choice where the net profit back to a plant covers the higher cost of acid production relative to limestone scrubbing. However, since costs of abatement, even using limestone scrubbing, exceed $100 per ton of H_2SO_4 equivalent for most plants; a third alternative, that of using clean coal, is likely to become attractive. A number of smelters are located in areas lacking adequate markets for sulphuric acid, which will likely result in neutralization and discard of some of this output. Moreover, in light of energy supply considerations, attention has been focussed on conservation, which will moderate growth in fossil fuel consumption, the major source of sulphur emissions.

Table 11. World production of sulphur in all forms, 1975

	Elemental	Other[1]	Total[2]
	(thousands of tonnes)		
United States	10 345	1 451	11 795
U.S.S.R.	2 812	6 650	9 462
Canada	6 717	700	7 417
Poland	4 754	285	5 039
Japan	749	1 655	2 404
Mexico	2 149	60	2 209
France	1 832	109	1 941
Spain	4	1 554	1 558
West Germany	520	552	1 072
Italy	60	650	710
Finland	84	426	510
Iran	475	—	475
East Germany	115	250	365
South Africa	25	330	355
Sweden	9	257	266
Norway	4	257	262
Others	1 938	4 068	6 005
Total	32 592	19 254	51 845

Source: British Sulphur Corporation Limited, November/December 1976.
[1]Sulphur in other forms includes sulphur contained in pyrites, and contained sulphur recovered from metallurgical waste gases, mostly in the form of sulphuric acid. [2]Totals may not add due to rounding.
— Nil.

Under the influence of these factors, and coupled with demand for fertilizers, sulphur inventories should peak in the next few years and supply and consumption will tend toward a balance, perhaps reaching that point in the early 1980s.

Prices

A firming trend, which characterized prices over the last few years, was interrupted by the present recession. A resistance to price erosion despite sharply reduced sales was evident and, in fact, prices in the United States were raised from \$45 to \$55 for Gulf port in 1974 to the \$60 level. This development is probably a reflection of the more than doubling of Frasch production costs in recent years. A recovery in the world economies should result in increased prices although there would likely be a lag of several months while customer inventories were being run down.

Canadian sulphur prices quoted in Canadian Chemical Processing, October, 1976.

	(\$)
Sulphur, elemental, fob works, contract, carload, per long ton	23.50
Sulphuric acid, fob plants East, 66° Be, tanks, per short ton	45.40

United States prices in U.S. currency, quoted in Engineering and Mining Journal, January 1977.

	(\$)
Sulphur elemental	
U.S. producers, term contracts fob vessel at Gulf ports,	
La. and Tex., per long ton (nominal)	
Bright	61.00
Dark	60.00
Export prices, for Gulf ports	
Bright	65 — 73
Dark	64 — 72
Mexican export fob vessel per long ton	
Bright	61
Dark	60

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
92503-1	Sulphur of all kinds, other than sublimed sulphur, precipitated sulphur and colloidal sulphur	free	free	free	free
92802-1	Sulphur, sublimed or precipitated, colloidal sulphur	free	free	free	free
92807-1	Sulphur dioxide	free	free	free	free
92808-1	Sulphuric acid, oleum	10%	15%	25%	10%
92813-4	Sulphur trioxide	free	free	free	free

United States

Item No.			Item No.		(%)
418.90	Pyrites	free	422.94	Sulphur dioxide	
415.45	Sulphur, elemental	free		On and after Jan. 1, 1970	8.5
416.35	Sulphuric acid	free		On and after Jan. 1, 1971	7
				On and after Jan. 1, 1972	6

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. Tariff Schedules of the United States, Annotated (1976), T.C. Publication 749.

Talc, Soapstone and Pyrophyllite

G.H.K. PEARSE

Talc is a hydrous magnesium silicate $H_2Mg_3(SiO_3)_4$ formed by the alteration of rocks rich in magnesia (most commonly ultrabasic igneous rocks and sedimentary dolomite) within which it occurs as veinlets, tabular bodies, or irregular lenses. It is a soft, flaky mineral with a greasy feel or "slip", it is readily ground to a fine white or nearly white powder, has a high fusion point, low thermal and electrical conductivity and is relatively chemically inert. Most of the uses of talc depend on individual physical properties or combinations of these properties.

Talc is produced in various grades which are usually classified by end use: cosmetic, ceramic, pharmaceutical and paint. A special, high-quality block talc used in making ceramic insulators and other worked shapes is designated steatite grade.

Soapstone is an impure talcose rock generally occurring in massive, compact deposits from which blocks can be sawn. Soapstone has been used since early times in many parts of the world for carving ornaments, pipes, cookware, lamps and other utensils. The art of carving this rock has survived among the Eskimos up to the present era. Present uses include metalworkers' crayons, refractory bricks, and blocks for sculpturing.

Pyrophyllite is a hydrous aluminum silicate $H_2Al_2(SiO_3)_4$ formed by hydrothermal alteration of acid igneous rocks, predominantly lavas which are andesitic to rhyolitic in composition. It resembles talc in physical properties and for this reason finds uses similar to talc, notably in ceramic bodies and as a filler in paints, rubber and other commodities.

In Canada, talc is produced in two provinces, Quebec and Ontario, while pyrophyllite is produced only in Newfoundland. Although the value of talc and soapstone shipments increased from $1 147 043 in 1975 to $1 358 000 in 1976, it remains well below the record $2.1 million 1973 value. The value of pyrophyllite production increased from $391 073 in 1975 to $416 000 in 1976 but similarly remained below the peak $560 010 value in 1973.

Production and developments in Canada

Talc, Soapstone. The earliest recorded production in Canada was in 1871-72 when 270 tonnes* of cut soapstone valued at $1,800 were shipped from a deposit in L 24, R 6 in Bolton Township, southern Quebec, by Slack and Whitney. In 1896 a deposit in Huntingdon Township, in the Madoc district of Ontario, was opened and over the next few years numerous deposits were discovered in this area and mined intermittently.

Several deposits in southern British Columbia and one in southwestern Alberta were discovered prior to 1920 and some of these were worked in a small way. At present, talc is mined by three companies — two in Quebec and one in Ontario.

Baker Talc Limited produces talc and soapstone from an underground mine in South Bolton, Quebec, 95 kilometres southeast of Montreal. Ore from the mine is trucked 16 kilometres south to the company's mill facilities at Highwater. In former years, Baker Talc produced a relatively low-grade, low-cost product suitable for use primarily as a dry-wall joint filler, asphalt filler and dusting compounds for asphalt roofing. Tests conducted in 1967-68, employing a Jones High Intensity Wet Magnetic Separator, demonstrated that the company's talc could be upgraded for use in the paint, cosmetic and paper industries and this process was added to the mill circuit in 1969. This project was supported by the federal Department of Industry, Trade and Commerce. Subsequently, a modified flotation process replaced the magnetic separator, which resulted in improved output. Shaft sinking to the 182-metre level was completed in 1976 and development work at this level was begun.

Current output of high-grade product, destined largely for paper mills, is around 5 000 tonnes a year. Expansions, begun in 1973, were completed during

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Talc, soapstone and pyrophyllite production, trade and consumption, 1975-76.

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Talc and soapstone				
Quebec[1]	. .	522 662	. .	794 000
Ontario[2]	. .	624 381	. .	564 000
Total	. .	1 147 043	. .	1 358 000
Pyrophyllite				
Newfoundland	. .	391 073	. .	416 000
Total Production	66 029	1 538 116	65 000	1 774 000
Imports (Talc)				
United States	30 237	2 296 000	46 240	2 874 000
Italy	69	15 000	148	21 000
Other countries	122	15 000	9	1 000
Total	30 428	2 326 000	46 397	2 896 000
	1974r		1975p	
Consumption[3] (ground talc available data)				
Ceramic products	7 334		7 042	
Paints and wall joint sealers	9 384		8 340	
Roofing	6 808		6 120	
Paper and paper products	6 411		4 340	
Rubber	1 190		1 392	
Gypsum products	3 475		6 414	
Toilet preparations	788		755	
Cleaning compounds	202		397	
Pharmaceutical preparations	1 751		1 514	
Linoleum, tile & floor covering	725		797	
Other products[4]	3 058		3 421	
Total	41 126		40 532	

Source: Statistics Canada.
[1]Ground talc, soapstone, blocks and crayons. [2]Ground talc. [3]Breakdown by Mineral Development Sector. [4]Chemicals, foundries, insecticides and other miscellaneous uses.
p Preliminary; . . Not available; r Revised.

1974, however, the economic downturn reduced sales during the latter half of that year and throughout 1975 and 1976. Minor shipments have also been made for use as a filler in plastics and paints and, from time to time, the company markets soapstone blocks as an artistic medium to schools and shops.

Broughton Soapstone & Quarry Company, Limited, quarries talc and soapstone from two deposits near Broughton Station in the Eastern Townships of Quebec, where the same geological conditions as in the South Bolton area are evident. Several low-priced grades of ground talc are produced, and soapstone is sawn to produce metalworkers' crayons and various sizes of blocks for sculpturing and plates for etching. Much of the Eskimo artists' soapstone requirements are supplied by this company.

Canada Talc Industries Limited produces talc from underground workings at Madoc, Ontario. The deposits at Madoc are extensive and were formed by the alteration of dolomitic marble. Tremolite and dolomite impurities in the deposit limit the use of some ground products. A high-quality product suitable as a filler material in the paint industry is produced.

Canadian Johns-Manville Company, Limited brought their Penhorwood township deposit into production in July 1976 but closed both this operation and one in California in December, having decided to get out of the talc business. The figures given in the tables

Table 2. Production and trade, 1965, 1970, 1974-76

	Production[1]			
	Talc and Soapstone	Pyro-phyllite[2]	Total[3]	Imports Talc
	(tonnes)			
1965	20 596	27 337	47 933	25 272
1970	. .	. .	65 367	29 999
1974	. .	. .	85 952	35 947^r
1975	. .	. .	66 029	30 428
1976^p	. .	. .	65 000	46 397

Source: Statistics Canada.
[1]Producers' shipments; [2]Producers' shipments of pyrophyllite, all exported; [3]From 1970, breakdown of producers' shipments not available for publication.
^{p}Preliminary; ^{r}Revised; . . Not available.

do not include product from the Penhorwood deposit.

Numerous deposits of talc and soapstone occur in other parts of Canada. A soapstone deposit on Pipestone Lake in Saskatchewan was worked by Indians for the manufacture of pipes and various utensils. Reserves are reported to be considerable. High quality "blue" talc was investigated in the Banff area of Alberta and British Columbia during the 1930s. In the Northwest Territories, a few occurrences of soapstone are known from which Eskimos obtained material for carving. Showings of minor importance occur at several localities in Nova Scotia and Newfoundland.

Pyrophyllite. Newfoundland Minerals Limited, a subsidiary of American Olean Tile Company, Inc. produces pyrophyllite from an open-pit mine near Manuels, 19 kilometres southwest of St. John's, Newfoundland. Ore is crushed, sized and hand-cobbed at the mine site prior to being trucked a short distance to tidewater. Continuous chemical analyses and physical tests are run on all material delivered from the mine to the loading dock. Blended ore is shipped in bulk to the parent company's operation at Lansdale, Pennsylvania where it is used in the manufacture of ceramic tile. Annual production varies between 25 000 and 35 000 tonnes. The pyrophyllite deposit at Manuels appears to be a hydrothermal alteration of sheared rhyolite. Altered zones are associated for the most part with extensive fracturing near intrusive granite contacts. Reserves are extensive.

Other known pyrophyllite deposits in Canada include an extensive area of impure pyrophllite near Stroud's Pond in the southern part of Burin Peninsula, Newfoundland; a deposit near Ashcroft, British Columbia; and three deposits on Vancouver Island, British Columbia, in the Kyuquot Sound area, 320 kilometres northwest of Victoria. The Vancouver Island deposits were worked on a limited scale in the early part of this century.

Table 3. World production of talc, soapstone, and pyrophyllite, 1974-76

	1974	1975^p	1976^e
	(tonnes)		
Japan	1 573 857	1 191 579	1 633 000
United States	1 169 781	841 458	1 029 000
U.S.S.R.	410 000	420 000	. .
South Korea	442 092	415 875	. .
France	298 330	258 000	272 000
Brazil	201 184	202 000^e	. .
India	264 685	200 122	. .
People's Republic of China	150 000^e	150 000^e	. .
Italy	154 965	137 800^e	145 000
North Korea	120 000^e	130 000	. .
Finland	128 269	124 260	127 000
Norway	113 026	120 000^e	. .
Australia	85 682	90 000^e	. .
Austria	98 440	86 512	. .
Peru	80 000^e	80 000^e	. .
Canada	85 952	66 029	65 000
Other countries	329 368	341 306	2 384 000
	5 705 631	4 854 941	5 655 000

Sources: U.S. Bureau of Mines, Mineral Trade Notes, Vol. 73, No. 11, November 1976, U.S. Bureau of Mines, Commodity Data Summaries, January 1977, Statistics Canada.
^{p}Preliminary; ^{e}Estimated; . . Not available.

Trade and markets

Most talc and soapstone produced in Canada is consumed domestically, while all pyrophyllite produced is exported. Imported talc, most of it from the United States, is high-quality, high-value material suitable for use in the paint, ceramics, paper and cosmetic industries. Production of these superior grades of talc in Canada began in 1970 with the new beneficiation techniques incorporated into Baker Talc's mill, and in 1971 a product acceptable to the pulp and paper industry was marketed. The Penhorwood township deposit, now closed, is reportedly of this quality. It is anticipated that imported high-quality talc will gradually be displaced to some extent in other industries by domestic product. However, imports, nearly all from the United States, in 1976 amounted to 46 397 tonnes valued at $2 896 000, up more than 50 per cent in tonnage but only 25 per cent in value compared with 1975. An 18 per cent increase in housing starts in 1976 may account for the increased imports of lower-value talc which would be required for roofing, floor tiles, wall board, wall joint sealer and the like. Average value of imports in 1976 was $62 a tonne while domestic production sells in the range of $10-75 a tonne, depending upon quality.

Uses

Talc is used mostly in a fine-ground state; soapstone in massive or block form. There are many industrial applications for ground talc, but major consumption is limited to less than a dozen industries.

Talc is used as a filler material in the manufacture of high-quality paper where it aids in dehydration of the pulp, improves sizing characteristics, reduces the tendency of papers to yellow and assures a well-bonded surface to promote ease of printing. For use in the paper industry, talc must be free of chemically active compounds such as carbonates, iron minerals and manganese; have a high reflectance, possess high retention characteristics in the pulp, and be free of abrasive impurities. Micronized material provides a high-gloss finish on coated papers.

The ceramic industry utilizes very finely ground talc to increase the translucence and toughness of the finished product and aid in promoting crack-free glazing. For use in ceramics, talc must be low in iron, manganese and other impurities which would discolour the fired product.

High-quality talc is used as an extender pigment in paints. Specifications for a talc pigment, as established in ASTM Designation D605-69, relate to the chemical composition, colour, particle size, oil absorption and consistency of, and dispersion in, a talc-vehicle system. A low content of carbonates, a nearly white colour, a fine particle size with controlled particle size distribution and a specific oil absorption are important. However, because of the variety of paints, precise specifications for talc pigments are generally based on agreement between consumer and supplier. Paint characteristics influenced by the use of talc as an extender are gloss, adhesion, flow, hardness and hiding power.

Talc is well known for its use in pharmaceutical preparations and cosmetics. It is the major ingredient in face, baby and body powders. Finely ground, high-purity material is used as a filler in tablets and as an additive in medical pastes, creams and soaps. Material used for these purposes should be free of deleterious chemical compounds, abrasive impurities and fibrous minerals such as tremolite and asbestos, which are believed to be injurious to health when inhaled or ingested.

Lower-grade talc is used as a dusting agent for asphalt roofing and gypsum board, as a filler in drywall sealing compounds, as a filler material in floor tiles, in asphalt pipeline enamels, in auto-body patching compounds, as a carrier for insecticides, as a filler or dusting compound in the manufacture of rubber products.

Other applications for talc include use in cleaning compounds, polishes, electrical cable coating, plastic products, foundry facings, adhesives, linoleum, textiles and in the food industry.

Particle-size specifications for most uses require the talc to be minus 325 mesh. The paint industry demands from 99.8 to 100 per cent minus 325 mesh. For rubber, ceramics, insecticides and pipeline enamels, 95 per cent minus 325 mesh is usual. In the wall-tile industry 90 per cent minus 325 mesh is generally required. For roofing grades the specification is about minus 80 mesh, with a maximum of 30 to 40 per cent minus 200 mesh.

Soapstone has now only very limited use as a refractory brick or block but, because of its softness and resistance to heat, it is still used by metalworkers as marking crayons. The ease with which it can be carved makes it an excellent artistic medium.

Pyrophyllite can be ground and used in much the same way as talc, but at present the use of the Canadian material is confined to ceramic tile. It must be minus 325 mesh and contain a minimum of quartz and sericite, which are common impurities.

World review

Deposits of talc are widely distributed throughout the world, but have been commercially developed only in the more industrialized countries. Because talc is of relatively low unit value, only a very small proportion of world production is traded internationally. The majority of international trade takes place within Europe, in the Far East between Japan, the People's Republic of China and Korea; and in North America between Canada and the United States. However, talc of exceptional purity is valuable enough to withstand the cost of transportation over much greater distances. For example, high-grade French, Italian, Indian and Chinese talcs are shipped throughout the world.

Prices

United States talc prices according to Oil, Paint and Drug Reporter, December 27, 1976.

	($ per short ton)
Canadian	
Ground, bags, carlot, fob mines	20.00-35.00
Vermont	
Domestic, ordinary, off-colour, ground, bags, carlot, fob works	22.25
California	
Domestic, ordinary off-colour, bags, carlot, fob works	34.00-39.50
New York	
Domestic fibrous ground bags	35.50

Tariffs

Canada

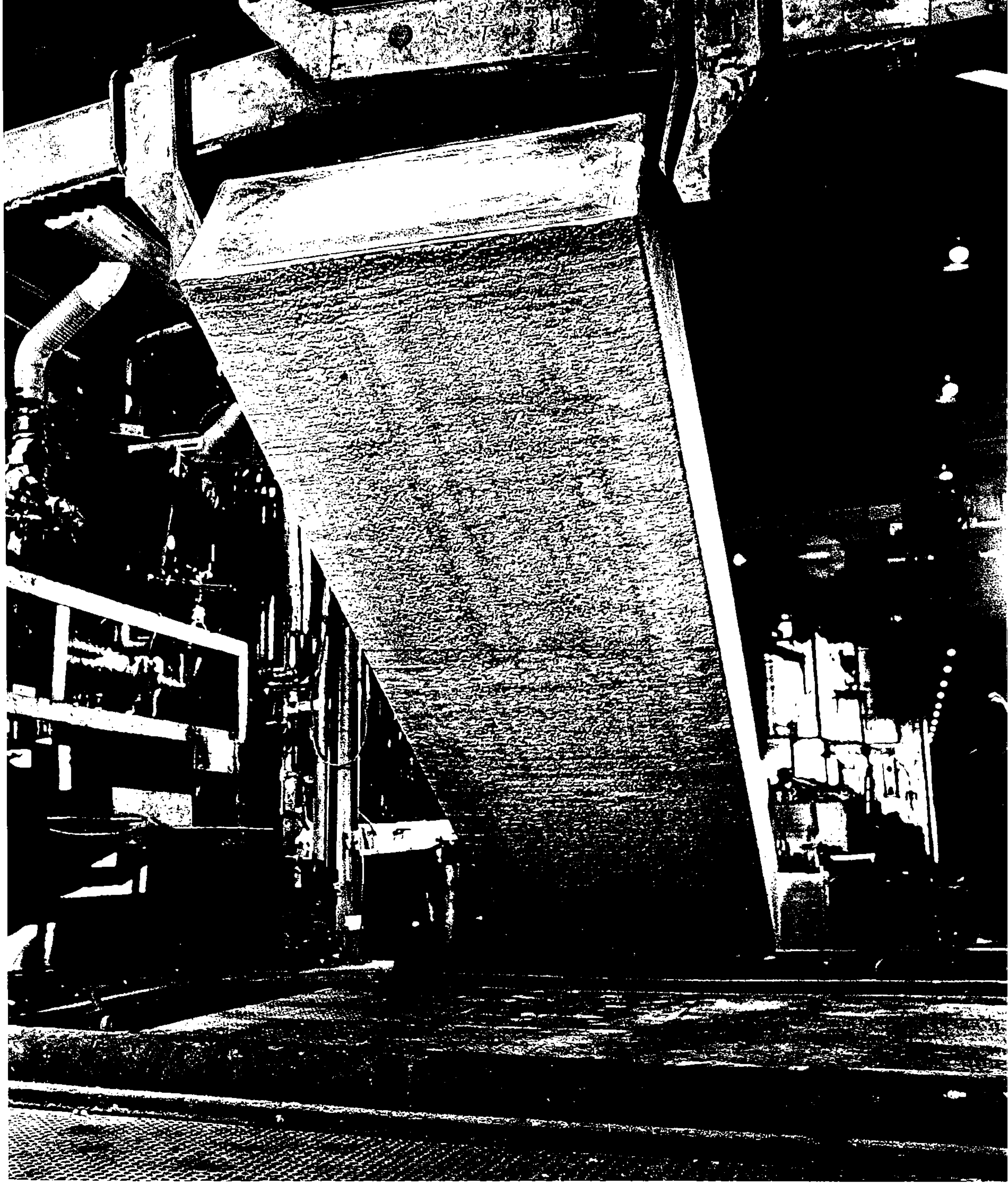
Item No.		British Preferential	Most Favoured Nation	General	General Preferential
		(%)	(%)	(%)	(%)
71100-3	Talc or soapstone	10	15		10
71100-8	Micronized talc	free	5		free
29655-1	Pyrophyllite	free	free	25	free
29645-1	Talc for use in manufacturing of ceramic tile (expires Feb. 28, 1977)	free	free	25	free
29646-1	Talc for use in manufacture of pottery (expires Feb. 28, 1980)	free	free	25	free

United States

Talc, steatite, soapstone

Item No.		
523.31	Crude and not ground	0.02¢ per lb
523.33	Ground, washed, powdered, or pulverized	6%
523.35	Cut or sawed, or in blanks, crayons, cubes, disks, or other forms	0.20¢ per lb
523.37	All other, not provided for	12%

Sources: For Canada, The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States, Annotated (1976), TC Publication 749.



Removing a sheet ingot from a mould at the Arvida, Quebec, works of the Aluminum Company of Canada, Limited (Alcan).

Alcan photo

Tin

G.S. BARRY

Tin is one of the few metals that Canada imports in large quantities. Domestic production is small and is exported in the form of concentrates to the United States, the United Kingdom and Mexico. Mine production is not sufficient to support a domestic smelter.

Canadian production of tin in concentrates and lead-tin alloy in 1976 was 275 tonnes*, valued at $1 873 000.

Canadian industrial requirements of tin are met mainly by imports that totalled 4 220 tonnes in 1976, valued at $31 710 000.

Canada also imports small quantities of tinplate (less than 1 per cent of domestic production), mainly from the United States. Tin metal scrap and tinplate scrap is mainly exported to the United States, as facilities for secondary metal processing in Canada are very limited. Tin-bearing secondary solders are recovered in a few plants; for example, Federated Genco Limited at its Scarborough, Ontario, plant. These are mainly melted away from products such as car radiators and pipes, and are re-constituted as solders. Statistics on the amounts recovered, however, are not available.

M & T Products of Canada Limited, Hamilton, Ontario recovers a secondary tin product by de-tinning industrial and municipal scrap. The product is potassium stannate, used mainly in electroplating applications. An equivalent of 120 to 140 tonnes of tin is thus recovered annually.

Traditionally, Malaysia was the main supplier of Canadian requirements of tin, but this pattern has been inconsistent since 1974. More than 50 per cent of our imports in 1974 came from the United States, but Malaysia returned as the leading supplier in 1975. In 1976, however, the United States became once again the main supplier of Canadian imports, but total imports decreased by 6 per cent as the industry continued to use tin from large inventories accumulated in 1974. Tin consumption is directly associated with demand for consumer goods and because of buoyant conditions for such goods, recovered much faster than most other metals of the nonferrous sector in 1976.

Until the end of 1973, Cominco Ltd. was the only mine producer of tin, recovering cassiterite (SnO_2) as a byproduct from milling lead-zinc ores at Kimberley, British Columbia. In the past few years the company's annual output was between 100 and 150 tonnes; in 1976, however, production dropped to 66.7 tonnes, but it is expected that production in 1977 will reach normal levels. Besides the tin concentrate recovered at Kimberley, Cominco recovers about 600 tonnes annually of a lead-tin alloy from treatment of lead bullion dross in the indium circuit of its Trail smelter. The tin content of this alloy is about 8 per cent. The company also produces, from purchased commercial-grade metal, small quantities of *Tadanac* brand high-purity tin (99.9999 per cent) and special research grade (99.999 per cent) tin.

Texasgulf Canada Ltd., a subsidiary of Texasgulf Inc., completed construction of a tin-circuit at its base metal concentrator at Timmins in the spring of 1974. This installation was designed to recover approximately 800 000 kilograms of tin annually, but recoveries during 1974, 1975 and 1976 were below expectation and production targets were not reached. The company initially directed efforts to achieving grade levels of about 54 per cent tin in the concentrate. Subsequently the company also experimented in the production of much lower grade concentrates, thus improving overall tin recovery. During 1976 Texasgulf produced 198.6 tonnes of tin. Concentrates averaged about 36 per cent tin and were sent to the Capper Pass plant in the United Kingdom for smelting.

Fine-grained cassiterite is a mineralogical component of sulphide ores at several Canadian mines but its economic recovery is possible only at the Sullivan mine of Cominco and the Kidd Creek mine of Texasgulf, mentioned above. Ore grades at these mines are between 0.15 and 0.25 per cent SnO_2. Tin is present in small quantities in the zinc-lead ore-bodies of

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Brunswick Mining and Smelting Corporation Limited, New Brunswick and in the South Bay, Ontario mine of Selco Mining Corporation Limited.

Brunswick Tin Mines Limited, 89 per cent held by the Sullivan Mining Group Ltd., continued exploration and metallurgical testing on its multimineral deposit in southwestern New Brunswick. Reserves for the Fire Tower Zone (FTZ) reported in 1973 are 29.5 million tonnes, with an average grade of 0.20 per cent tungsten, 0.09 per cent molybdenum, 0.08 per cent bismuth, 0.04 per cent tin, 0.07 per cent copper, 0.35 per cent zinc, 0.08 per cent lead, 4 per cent fluorspar and about one ounce of indium a tonne. In addition, diamond drilling completed in 1974 and 1975 on the North Zone, a little more than half a mile north of the Fire Tower deposit, indicated 12 500 000 tonnes grading 0.241 per cent WO_3, 0.08 per cent MoS_2, 0.08 per cent Bi and some tin. Of the above tonnage, 2 600 000 tonnes graded 0.42 per cent tin, 0.077 per cent WO_3, 0.05 per cent MoS_2 and 0.06 per cent Bi.

Some $1.4 million were spent during the 1975-76 fiscal year to evaluate the property. Metallurgical tests were conducted on ore from the Fire Tower Zone using gravity and flotation methods of concentration. Management was encouraged by results to date and expects that a production decision could be made in 1977. The property will require some $30 millions to bring into production and the corporation is seeking partners with capital.

The principal use of tin in Canada, accounting for over 50 per cent of the total consumption, is in the production of tinplate. There are two producers: Dominion Foundries and Steel, Limited (Dofasco) and The Steel Company of Canada, Limited (Stelco), both at Hamilton, Ontario. Canadian output of tinplate is all electrolytic; hot-dip production ceased in 1966. It is estimated that in 1975, 2 286 tonnes of tin were used to produce 449 100 tonnes of tinplate, and in 1976, 2 434 tonnes to produce 477 100 tonnes of tinplate, which indicates that further economies were made by the application of thinner coatings of tin. The average tin weight fell from 5.42 kilograms a tonne in 1975 to 5.10 kilograms a tonne in 1976.

Dofasco and Stelco each operate three electrolytic tinplate lines. Stelco's third line, with a capacity of 175 000 tonnes of tinplate a year, was commissioned in November 1971. It can be converted to produce steel with other types of coatings, notably chrome-coated steel. Dofasco's third line is also dual purpose, and was commissioned in March 1972. It doubled the company's tinplate manufacturing capacity.

The second-largest use for tin is in the manufacture of solders. Between 1 500 and 2 000 tonnes of tin are used annually for this product. Important Canadian users of tin for this application are The Canada Metal Company, Limited, Federated Genco Limited, Cramco Alloy Sales Limited, Kester Solder Company of Canada Limited, Tonolli Company of Canada Ltd., Toronto Refiners and Smelters Limited, and Metals & Alloys Company Limited. Bronze, a copper-lead-tin alloy, is also produced in Canada, chiefly by Noranda Metal Industries Ltd., Anaconda Canada Limited, Federated Genco Limited, Metals & Alloys Company Limited, The Ingot Metal Company Limited, and General Metals Industries Ltd.

World developments

More than 75 per cent of the world tin mine output is derived from alluvial deposits. The principal method is by bucket-line dredging which can be used to a water depth of 150 feet. The suction dredge is also used, but in most places is less efficient than the bucket-line. Other methods are gravel pumping, hydraulicking and dulang washing. Tin is recovered as cassiterite (SnO_2) and at times is associated with other metals such as wolframite (tungsten).

Placer deposits are easy to mine and, as a result, relatively low concentrations of tin are economic. A typical economic grade is about 0.4 pounds per cubic yard of sand (approx. 3 000 lbs) or a tenor of only 0.013 per cent tin.

Leading countries in this field of extraction are Malaysia, Thailand, Indonesia and Nigeria. This is a labour-intensive industry as some 130 000 people are employed in the four countries mentioned.

Lode mining is far less common than alluvial mining but still accounts for most of the tin output of Bolivia, Australia, Britain and South Africa. Some other countries of the western world produce small amounts. Countries of the communist and socialist blocks, notably The People's Republic of China and the U.S.S.R., are also important producers. Statistics for these countries are not available, but their total production is estimated to be in the range of 36 000 to 40 000 tonnes annually. Lode deposits usually have a minimum tin content of 0.4 per cent and many mines in Bolivia, Australia and Britain have grades of about 1 per cent. Silver, tungsten, and lead are common byproducts of lode mines. Cassiterite is also the predominant tin-bearing mineral of lode deposits but stannite, a copper-tin-iron-bearing sulphide is of some importance. The high cost of mining lode deposits is mainly attributed to the necessity for underground mining of narrow vein-type deposits.

Total noncommunist world output of tin in concentrates in 1976 is estimated at 178 000 tonnes by the International Tin Council. This is a small increase from the production of 177 500 tonnes for 1975, and is still well below the 194 300 tonnes recorded in 1972. The principal reason mentioned for this lack of improvement is the low level of investment in the tin extractive industry in the traditional mining countries of the Far East and in Africa.

Concentrating processes for alluvial and most lode tin are chiefly based on relatively simple gravity separation methods that produce concentrates ranging from 50 to 76 per cent tin. Typical concentrates as delivered, for example, to Malaysian and Indonesian smelters in 1976 graded 65 to 75 per cent tin. Lode

Table 1. Canada, tin production, imports and consumption 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production				
Tin content of tin concentrates and lead-tin alloys	319	2 366 202	275	1 873 000
Imports				
Blocks, pigs, bars				
United States	1 181	8 830 000	2 504	19 879 000
Australia	484	3 346 000	1 133	7 761 000
Bolivia	—	—	165	1 247 000
Brazil	448	3 212 000	197	1 078 000
Netherlands	257	2 213 000	109	942 000
Malaysia	1 637	11 798 000	94	667 000
United Kingdom	97	769 000	18	136 000
Other countries	387	2 908 000	—	—
Total	4 491	33 076 000	4 220	31 710 000
Tinplate				
United States	1 704	769 000	1 723	741 000
United Kingdom	182	141 000	132	99 000
West Germany	4 810	2 238 000	2	1 000
Total	6 696	3 148 000	1 857	841 000
Tin, fabricated materials, nes				
United States	180	232 000	176	635 000
United Kingdom	11	37 000	13	45 000
West Germany	1	5 000	14	30 000
Other countries	1	7 000	2	3 000
Total	193	281 000	205	713 000
Exports				
Tin in ores and concentrates*				
United Kingdom	256	219 000	427	912 000
Spain	—	—	109	410 000
United States	709	1 700 000	168	246 000
Other countries	87	259 000	—	—
Total	1 052	2 178 000	704	1 568 000
Tinplate scrap				
United States	6 285	434 000	4 987	356 000
Venezuela	—	—	81	14 000
Argentina	—	—	76	10 000
Other countries	32	3 000	57	6 000
Total	6 317	437 000	5 201	386 000
Consumption				
Tinplate and tinning	2 407	..	2 524	..
Solder	1 525	..	1 829	..
Babbit	152	..	195	..
Bronze	112	..	117	..
Other uses (including collapsible containers, foil, etc.)	119	..	184	..
Total	4 315	..	4 849	..

Source: Statistics Canada.
*Gross weight of concentrates.
p Preliminary; — Nil; nes Not elsewhere specified; .. Not available.

Table 2. Canada, tin production, exports, imports and consumption, 1965-76

Year	Production[1]	Exports[2]	Imports[3]	Consumption[4] Recorded	Consumption[4] Unrecorded
			(Tonnes)		
1965	171	219	5 073	4 910	
1966	322	342	4 322	5 052	
1967	198	331	4 621	4 889	
1968	163	119	4 369	4 319	
1969	131	313[e]	5 024	4 349	450[e]
1970	120	272[e]	5 111	4 554	500[e]
1971	144	296[e]	5 104	4 056	800[e]
1972	160	379[e]	5 906	4 760	700[e]
1973	132	127[e]	5 465	5 235	100[e]
1974	324	550[e]	5 556	5 425	50[e]
1975	319	370[e]	4 491	4 315	50[e]
1976	275	300[e]	4 220	4 849	..

Source: Statistics Canada.
[1]Tin content of tin concentrates shipped, plus tin content of lead-tin alloys produced. [2]Tin in ores and concentrates and tin scrap., and after 1969 also re-exported primary tin. [3]Tin metal. [4]Unrecorded means not included in official Statistics Canada records; also includes consumer stock changes.
[e] Estimated by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa; .. Not available.

mining companies in Australia, South Africa, and Britain have recently installed flotation cells in their beneficiating plants to complement gravity separation and improve the recovery of other metals, as well as some very fine tin. Another development now being implemented is split production of a high-grade concentrate and a low-grade concentrate. By producing low-grade concentrates of approximately 30 per cent tin, an overall improvement in recovery is achieved that may compensate for the substantially higher smelting charges that are incurred.

Malaysia. Malaysian tin production in 1976 fell for the fifth straight year. Production in 1976 was 63 401 tonnes compared with 64 364 tonnes in 1975. The number of individual operating units ("mines") slumped from 910 to 811. Since Malaysia also reported that a total of 189 "mines" ceased operations in 1976, the difference should be accounted for by resumption of mining activity at some previously idle workings and some new "mines". Lack of investment and high taxes are the chief reasons cited for the decline by the Malaysia Chamber of Mines. Export controls, however, in force in the second half of 1975 and the beginning of 1976, were also mentioned as the cause of some closures.

The record Malaysian production was 79 400 tonnes in 1941. At the end of 1976 Malaysia recorded production from 811 units, which included 51 dredges and 724 gravel pump operations. Dredges account for 36.5 per cent of production, gravel pumps for 50.0 per cent, and hand sluicing and panning for the remaining 13.5 per cent. The labour force was 36 828, a decrease from 39 736 in 1975.

Malaysia has two tin smelters in Penang. Both smelters have capacities considerably in excess of current production. The Straits Trading Co. Ltd. has a 60 000-tonne smelter at Butterworth, and Datuk Keramat Smelting Sdn Bhd (50.5 per cent owned by Amalgamated Metal Corporation Ltd.) a 70 000-tonne smelter in Georgetown. The smelters jointly produced 78 017 tonnes of tin in 1976 from domestic and imported ores, compared with 83 070 tonnes in 1975. Besides export controls that handicapped the industry at the beginning of 1976, the same problems as those identified in 1975 persisted, the increasingly lower-grade tin-bearing ores, sharply rising production costs, particularly the fuel component; high taxes, and bureaucratic problems associated with proposals for new and expanded production. Despite the very substantial increase in tin prices achieved during 1976 the volume of output did not increase, but hopefully, statistics for early 1977 will show long-expected improvement. In the past, Government officials pointed solely to a direct relationship between the price of tin on international markets and the lack of investment in tin. This was suspected to be an over-simplication of the problem. If substantially improved prices prevail in 1977 and 1978, then there should be indications as to what other structural changes need to be introduced before Malaysia once again can increase output in its tin mining and smelting industry.

Most of the Malaysian tin deposits lie in a strip about 650 kilometres long and less than 80 kilometres wide along the western coast. They are found near, or at, the contact zone between sediments and granitic massifs known as the Main Range. The States of Perak and Selangor account for most of the output, with the world-famous Kinta Valley in Perak being the most prolific tin mining area since the 1890s. All deposits are alluvial, and the extension of deltaic formations from streams and rivers all along the coast make this coastal zone of the Strait of Malacca an important region for intensive ocean dredging in the future.

Malaysia is not expected to increase mine output over the next five-year period. Capital investment is low and problems in obtaining mining leases are substantial. There is very strong opposition at the state level to further mining development. Land utilization and environmental issues have increasingly been taken into account but the main opposition stems from the fact that the State governments receive little tax revenue from the tin industry despite the high rate of tax levied on it.

Bolivia is the largest producer of tin from lode mines. A small proportion of annual output is derived from dredging operations. For 1976 Bolivia's mine production is estimated at 28 122 tonnes, of which approximately 18 000 tonnes were exported for smelting, mainly to Europe and the United States. In addition, the country's Vinto smelter, commissioned in January 1971 by Empresa Nacional de Fundiciones (ENAF), produced 9 525 tonnes of metallic tin compared with 7 133 tonnes in 1975.

The capacity of the Vinto smelter is being expanded from its initial rated capacity of 7 500 tonnes a year. The first phase of a two-phase expansion program was completed by the beginning of 1976. It raised the operational capacity for most of 1976 to 11 000 tonnes a year and included the installation of a rotary furnace and a second fuming furnace. Vinto can now treat all of the tin-bearing slag produced in the process, and also part of the slag stockpiled over the last few years. The final stage of expansion, which will raise capacity to 20 000 tonnes a year, is scheduled to be completed by 1977. Full capacity utilization is expected in 1978. It involves the addition of two reverberatory furnaces, six thermal refining kettles and five electrolytic cells. At completion of the final stage in 1977 total capital costs are estimated to be between $U.S. 40 million and $U.S. 45 million.

Bolivia's top priorities are the upgrading of tin in low-grade ores, and better recovery. Ores throughout the country, but particularly those of the Potosi area, are mineralogically very complex and of a very fine-grained nature, and therefore very difficult to concentrate. At present the recovery from the Potosi mines is in the range of 50 to 60 per cent when producing concentrates of over 20 per cent tin. To improve the overall tin recovery, the following extraction scheme has been designed for the Unificada mine at Potosi: a new gravity preconcentration plant, treating mill heads of about 0.8 per cent tin, will produce concentrates of only 3 per cent tin, but the recovery will be raised to about 70 per cent. A volatilization plant will treat this low-grade concentrate and the product will be a 50 per cent concentrate with a recovery of 90 per cent or better. However, the product of the volatilization plant, although high grade, is still too "dirty" to process in a conventional tin smelter and a "low-grade-tin smelter" will be constructed at the Vinto complex. The feed for the low-grade-tin smelter will be a mixture (about 1 to 1) of the 50 per cent tin concentrate from the Potosi volatilization plant and concentrates from various Corporacion Minera de Bolivia (Comibol) and private mines grading about 25 per cent tin.

The Potosi volatilization plant is now under construction using technology and loans provided by the U.S.S.R. Progress made during 1976 was satisfactory and the plant should be completed in 1977. At full capacity it will produce about 3 500 tonnes a year of tin (7 000 tonnes a year of concentrates). The design for a "low-grade-tin smelter" was completed in 1976. If construction starts in 1977 as originally anticipated, then it could be completed by 1979 and achieve full-capacity utilization by 1980. In addition to tin, this smelter will produce antimony, bismuth and some base metals. The tin-producing capacity will be about 10 000 tonnes a year. The U.S.S.R. (Machinoexport), Klockner-Industrieanlagen (West Germany) and Paul Bergsoe and Sons (Denmark) will jointly construct the low-grade-tin smelter. Capital costs for the completed facility, including installations for the recovery of byproduct metals, would be in the $U.S. 40 to 50-million range.

Pending evaluation of the success of the Potosi volatilization plants, plans are afoot for one or two others which could be installed to process ores, tailings and concentrates from such mines as Machacamara (at Oruro) San Jose y Queschisla, Catavi, Huanuni and Colquiri. The provision of adequate capital, however, will remain the main obstacle to expansions.

Indonesia. Mine production decreased to 22 418 tonnes in 1976 from 25 346 tonnes in 1975. The metal sector continued to expand for the fifth consecutive year, with an output of 23 322 tonnes in 1976 compared with 17 826 tonnes in 1975.

Table 3. Estimated world[1] production of tin in concentrates, 1966, 1975-76

	1966	1975	1976
		(tonnes)	
Malaysia	69 991	64 364	63 401
Bolivia	25 932	28 324	28 122
Indonesia	12 727	25 346	23 400
Thailand	22 927	16 406	20 453
Australia	4 884	9 310	10 389
Nigeria	9 687	4 652	3 710
Republic of Zaire	7 152	4 562	4 000
Total including countries not listed	167 100	177 500	178 000

Source: International Tin Council, *Statistical Bulletin.*
[1]Excludes countries with centrally-planned economies, except Czechoslovakia, Poland and Hungary. The People's Republic of China and the U.S.S.R., are large tin producers.

The Indonesia State Tin Enterprise, P.N. Tambang Timah, (also known as P.T. Timah), completed the expansion of its Peltim smelter (Mentok) on Bangka Island with the firing of the last of the three new reverberatory furnaces in December 1975, which accounted for the substantial increase in metal output recorded for 1976. Although each reverberatory furnace has a theoretical capacity of 8 000 tonnes a year, the practical maximum operational capacity of the system will be 18 000 tonnes a year and of the three old rotary furnaces 15 000 tonnes a year. The total annual refined metal capacity of 33 000 tonnes will afford an adequate margin for domestic smelting for the planned expanded mine output. Formerly, most of the Indonesian excess concentrates were shipped for smelting to Malaysia, but these shipments were discontinued in the second quarter of 1976. P.T. Timah is the largest of four companies that currently are engaged in tin exploitation in Indonesia.

P.T. Broken Hill Proprietary Indonesia is considering reopening the old Kelapa Kampit lode mine on Belitung Island. The mine was in production between 1906 and 1942. The mine has been partially dewatered and a pilot mill is now processing the ore from the first four levels. Some concentrate are also produced from two adjacent open pits, the Fuk Salu and Nam Salu workings. The final decision on whether PT BHP Indonesia will go to full production at some 500 tonnes of ore a day, is not expected before 1977. It is possible that the property will only be put on limited production and on a short-term basis. Nevertheless, the Kelapa Kampit mine and the surrounding primary tin deposits on Belitung Island and adjacent islands are considered by some geologists to be one of the best areas in the world for primary tin mineralization.

Mining in Indonesia takes place in four regions: Bangka, Belitung, Singkep and Bangkinang. Bangka Island accounts for just over 70 per cent; Bangkinang is the newest field and accounts for less than 1 per cent. There are over 40 dredges operating in Indonesia of which about a quarter are sea-going. While inshore reserves are substantial, Indonesia bases its aspirations for substantial increases in output on offshore reserves that are being constantly expanded. The largest of the offshore dredges Bangka I (in operation since 1966; 18 cu. ft. buckets) is the "flag-ship" of the tin mining fleet, and an order was issued during 1976 for the construction of Bangka II (22 cu. ft. buckets), a superdredge which will have an effective capacity in excess of 7 million cubic yards a year. It will cost approximately $U.S. 23 million, including spare parts, and will be built in Japan. It is scheduled for completion by 1979.

In late 1975 Billiton Exploration and Mining Co. (BEMI B.V.) reported the discovery of an important offshore tin deposit in the Pulau Tudju area off the coast of Sumatra. The company announced this success after seven years of prospecting, and plans to begin offshore dredging in 1978-79, producing at an initial annual rate of 2 430 tonnes of 70 per cent tin concentrate. It will be a joint venture between Billiton and P.T. Timah. BEMI B.V. will begin construction of a new superdredge in 1977 which will be completed in late 1978 or early 1979. It is designed to work all year round at a depth of up to 45 metres. It will have 30 cu. ft. buckets.

Tin mining in Indonesia is expected to continue at the present level of 23 000 to 25 000 tonnes per year until 1977-78. It is expected, however, to increase to the 27 000-tonnes-per-year level in the period from 1979 to 1982, which may be slightly short of the stated objective of 27 000 tonnes by 1980.

Thailand. Thailand's tin-mining production increased to 20 453 tonnes in 1976 from 16 406 tonnes in 1975. This is the first substantial increase after four consecutive years of decline, attributed chiefly to political and economic strife.

Dredging operations accounted for approximately 39 per cent of production; gravel pumping, hydraulicking and dulang washing for 45 per cent, with the remaining 16 per cent attributed mainly to several small lode mines and to illegally operating "suction-boats".

The allocation of concession rights, particularly offshore and exploitation permits, continued to be problems during 1976. The offshore concession of Thailand Exploration and Mining Co. Ltd. (Temco) was withdrawn in March 1975 by Thailand's minister of industry, "because it had failed to comply with government regulations". Temco is a Union Carbide Corporation-Billiton groups partnership, in which the Thai government has an 8 per cent interest. The company operated two offshore cutter suction dredges Temco I and Temco II. The largest, the Temco II dredge commissioned in 1971, has an annual capacity of 5 million cubic yards and was designed to operate in rigorous sea-dredging conditions. This unit, however, experienced considerable operating problems. The Temco concession was officially nationalized in April 1975 and subsequently the United States government requested the Thai government to either reconsider the offshore mining concession or pay compensation.

Meanwhile the Billiton company bought the Temco suction cutter dredge and plans to start operations in early 1977 on leases obtained jointly with the Off-shore Mining Organization (OMO). The longer-term future of offshore mining is unclear since it is believed that illegal mining by "suction-boats", which overran the leases in 1975 and 1976, resulted in sufficient high-grading to put in question the real value of concessions left behind. Some suction-boats were "legalized" in late 1976 and will remain in operation for a few more years. In general, total mining output in Thailand should reach about 22 000 tonnes per year in 1977 and 1978, but thereafter may either remain static or even decline to the 18 000-20 000-tonnes-per-year level by 1980.

The Phuket smelter of the Thailand Smelting and Refining Co. Ltd. (Thaisarco) produced 20 337 tonnes of tin in 1976 compared with 16 630 tonnes in 1975. The smelter has a capacity of 40 000 tonnes a year and was

Table 4. Estimated world[1] production of primary tin metal, 1966, 1975-76

	1966	1975	1976
	(tonnes)		
Malaysia	72 186	83 070	78 017
Indonesia	835	17 826	23 322
Thailand	17 261	16 630	20 337
United Kingdom	17 779	11 585	10 054
Bolivia	1 100	7 133	9 525
Brazil	1 845	5 400	6 600
Australia	3 724	5 254	5 593
United States	3 886	6 410	5 733
Spain	1 907	5 249	5 369
Belgium	5 058	4 562	4 068
Nigeria	10 092	4 677	3 667
Republic of South Africa	1 300	2 400	2 400
West Germany	1 384	1 306	1 449
Total, including countries not listed	157 200	175 500	179 700

Source: International Tin Council, *Statistical Bulletin*.
[1]Excludes countries with centrally-planned economies, except Czechoslovakia, Poland and Hungary.

commissioned in 1965 as a joint venture between Union Carbide (70 per cent) and the Eastern Mining Development Company (30 per cent). The latter company is now jointly owned by Union Carbide and Billiton. In 1975 Thaisarco decided to make its shares available to the public.

Australia is the fifth largest producer of tin in the noncommunist world. Its mine production increased to 10 389 tonnes in 1976 from 9 310 tonnes in 1975, which is back to the highest level, except for 11 997 tonnes reached in 1972.

Tasmania accounts for 61 per cent of the tin produced in Australia. The largest tin producer is Renison Ltd., which completed an expansion program that raised its capacity from about 4 000 to 5 000 tonnes a year. In 1976 Renison produced 4 533 tonnes of tin in concentrates compared with 3 783 tonnes in 1975. The company states that for both years production was curtailed as a result of export controls. The other two large producers in Tasmania are Abminco and Aberfoyle Tin N.L. which produced 1 691 tonnes and 142 tonnes in tin, respectively, in 1976. Abminco was formerly known as Clevelant Tin N.L.

The largest lode producer on the mainland is Ardlethan Tin N.L. in New South Wales with production of 1 263 tonnes in 1976.

In Western Australia production comes mainly from Greenbushes Tin N.L. The company extracts tin from a large open-pit operation, sited on deeply weathered primary ore lodes. Production in 1976 was 534 tonnes of tin concentrates.

A small net increase in total tin mine production is possible over the next few years, with modest expansions at the largest mines offsetting closures of several small alluvial operations due to depletion of reserves. Production is likely to peak at less than 12 000 tonnes a year and thereafter will remain static unless major new discoveries are made. Active exploration for lode deposits is in progress.

Associated Tin Smelters Pty Ltd., operates the only Australian primary tin smelter, located at Alexandria, N.S.W. The smelter is a joint venture of O.T. Lempriere & Company Ltd., Consolidated Tin Smelters (Australia) Pty Ltd, and Australian Iron & Steel Pty Ltd. Effective production capacity of the smelter is approximately 7 500 tonnes a year of tin (with the smelter being originally rated at 15 000 tonnes a year of concentrates). Production in 1976 was 5 604 tonnes compared with 5 254 tonnes in 1975. In addition, between 400 and 500 tonnes of secondary tin is produced annually by M&T Chemicals (Australia) Pty Ltd. at the Unanderra plant, N.S.W., and by Simsmetal Ltd. at Melbourne, Victoria.

Nigeria. In the mid-1940s Nigeria reached a peak tin production of nearly 13 000 tonnes, but since that time production has been declining, and reached its lowest level of 3 935 tonnes in 1976. Production in 1975 was 4 652 tonnes. The plight of the industry is mainly due to the complete lack of investment to modernize extraction which is being carried out by labour-intensive methods. Over 55 000 people are presently engaged in the tin sector, many of them private operators.

Amalgamated Tin Mines of Nigeria (Holdings) Ltd., is by far the largest tin mining company in Nigeria, being responsible each year for more than half of the country's output. The company invested £650 000 in 1975 and 1976 to put two bucket-wheel excavators into production at the Sabon Gida tinfield of the Jos Plateau of central Nigeria.

Unplanned exploitation led to the depletion of high-grade reserves and grades have been decreasing in the remaining workings. Periodic lack of rainfall affects the operation of gravel pumps and washing plants.

The decrease in the supply of domestic concentrates is reflected in the substantial decrease in tin metal production at the Makeri smelter at Jos. In 1976 metal production was 3 767 tonnes compared with 4 677 tonnes in 1975. Makeri Smelting Co. Ltd. is 79.2 per cent owned by Amalgamated Metal Corporation Ltd. (AMC). Legislation has been enacted in Nigeria which makes it compulsory for Makeri to have at least 40 per cent Nigerian shareholding by December 31, 1978.

Zaire. Production of tin in the Republic of Zaire has declined steadily since 1969. Production in 1976 was about 4 000 tonnes compared with 4 562 tonnes in 1975. In the 1940s production in Zaire (formerly the Congo) reached a peak of over 15 000 tonnes.

Mainly four companies were exploiting the tin deposits: Symetain, Cobelmines, Kivumines and Zaire-

Table 5. World[1] tin position, 1973-75 (and estimated 1976)

	1973	1974	1975	1976^e
	(thousands of tonnes)			
Ore supply				
Production of tin in concentrates	185.3	181.7	177.5	175.0
Stocks at year's end	12.1	10.2	15.6	7.5
Primary metal supply				
Smelter production of tin metal)	184.7	177.2	175.5	179.0
Net supplies (plus) from Sino-Soviet Bloc	(−)1.9	(+)4.9	(+)4.0	(−)2.8
U.S. Government stockpile sales	17.6	23.5	(+)0.6	(+)3.6
Buffer Stocks sales (+) purchases (−)	(+)11.5	(+)0.9	(−)19.9	(+)19.2
Primary metal consumption (I.T.C.)	212.1	199.4	172.5	190.0
Balance (metal)	(−)0.2	(+)7.1	(−)12.3	(+)9.0
Recorded commercial stocks: at year's end	37.9	39.2	42.7	35.7

Source: International Tin Council, *Statistical Bulletin.*
[1] Excludes countries with centrally planned economies; except Czechoslovakia, Poland and Hungary.

tain. From April 1976, the first three companies have been merged into a new company, Sominki. Sominki produced 3 315 tonnes of tin in 1976 and Zairetain produced 223 tonnes.

About 600 tonnes of tin were smelted domestically at the Manono plant. This smelter had an originally rated capacity of 15 000 tonnes, but a fire in 1960 severely damaged part of the plant so that its current capacity is rated at approximately 4 000 tonnes a year. The rest of Zaire's mine production is exported to Belgium and Spain for smelting.

Brazil. Mine production in 1976 was estimated at 5 900 tonnes compared with 5 000 tonnes in 1975, while metal production was 6 000 tonnes compared with 5 400 tonnes. Because some concentrates are exported, domestic concentrate requirements for smelting are supplemented by some imports, principally from Bolivia and Singapore.

The Brazilian government approved a program of expansion of the nonferrous industry which includes the objective of achieving self-sufficiency in tin output by 1983. It is doubtful, however, that this objective can be reached. The projected demand would be approximately 21 000 tonnes a year. Over the period of the past four years the Brazilian tin mining industry was rationalized, most small private groups that tended to high-grade deposits were eliminated and small companies were merged. At present, four companies account for three-quarters of Brazil's output. They are: Mineracao Brumadinho Ltda, Paranapenema S.A., Mineracao e Prospeccoes Minerais S.A., and Companhia Estanifera do Brasil.

Brazil has six smelters with a combined capacity of 14 100 tonnes a year of which the following are of importance: Companhia Estanifera do Brasil, at Volta Redonda, 6 800 tonnes a year; Companhia Industrial Amazonense, at Manaus, 2 400 tonnes a year; Mamore Min. e Metalurgia, at Sao Paulo, 2 400 tonnes a year. Bera do Brasil S.A. operated a 1 000-tonne-a-year smelter at Sao Paulo which is being closed and relocated in a new area outside Sao Paulo. Production statistics for individual smelters are not available. Brazil's consumption of tin in 1976 was estimated at 4 520 tonnes compared with 4 300 tonnes in 1975.

The most authoritative reports on Brazilian tin reserves are those of the National Mines Department, i.e. Departamento Nacional de Producao Mineral (DNPM), that placed the total reserves at approximately 300 000 tonnes, basis tin concentrates of 66 per cent. Of this total 180 000 to 200 000 tonnes are reserves in the most important Rondonia placer district.

United Kingdom. Mine production in 1976 was 3 323 tonnes, unchanged from the lows recorded for the previous two years. All mining takes place in the historic district of Cornwall in southwest England. There are five main mines: South Crofty, Pendarves, Wheal Jane, Geevor and Mount Wellington. Increased output from Cornwall will mainly be shown in the 1977 statistics. The Mount Wellington mine, next to Wheal Jane, was brought into production in February 1976 at a cost of over £5 million. It has an annual capacity of 6 000 tonnes of concentrates grading approximately 33 per cent tin.

The U.K. encourages exploration through their Mineral Exploration and Investment Grants Act of 1972 which provides for grants up to 35 per cent of exploration capital.

Metal production decreased in 1976 to 11 003 tonnes from 11 585 tonnes in 1975. The main metal producer from primary tin concentrates is the Capper Pass smelter. Williams, Harvey & Co., placed into a creditors voluntary liquidation in June 1973, continued in 1976

Table 6. World primary tin smelters; smelting capacity at end of 1976

Country	Ownership	Location	Capacity; 000 tonnes refined tin
Africa			
* Nigeria	Makeri Smelting Co. Ltd.	Jos	12.0
Rhodesia	Kamativi Smelting & Refining Co. Ltd.	Bulawayo	1.2
South Africa	Zaaiplatts Tin Mining Co. Ltd.	Potgietersrus	1.5
* Zaire	Zaïrétain (Géomines Cie.)	Manono	4.0
America			
Argentina	Soc. Min Pirquitas, Picchetti y Cia. S.A.	Buenos Aires	1.5
* Bolivia	Empresa Nacional de Fundiciones (ENAF)	Vinto (Oruro)	11.0[1]
Brazil	Cia. Estanifera do Brasil	Volta Redonda	6.8
	Cia. Industrial Amazonense	Manaus	4.8
	Mamore-Mineração e Metalurgia Ltda.	São Paulo	2.4
	Best Metais e Soldas S.A.	São Paulo	1.2
	Cia. Industrial Fluminense	São João Del Rey	0.6
	Bera do Brasil	São Paulo	0.4
Mexico	Cia. Estaño Electro, S.A. de C.V.	Tlalnepantla	1.2
	Fundidora de Estaño, S.A.	San Luis Potosí	0.5
	Metales Potosi, S.A.	San Luis Potosí	0.5
United States	Gulf Chemical & Metallurgical Corp.	Texas City, Texas	20.0
Asia			
China	Yunnan Tin Corp.	Kochiu, Yunnan	25.0
	Ping Kwei Mining Association	Papu, Ho-hsien, Kwangsi	10.0
* Indonesia	Indonesian State Tin Enterprise (P.N. Timah)	Mentok, Bangka Island	22.0
Japan	Mitsubishi Metal Mining Co. Ltd.	Naoshima	2.5
	Rasa Kogyo K.K.	Ohita	1.0
* Rep. of Korea	Pyro Metal Industry Co. Ltd.	Seoul	0.6
* Malaysia	Datuk Keramat Smelting Sdn Bhd	Georgetown, Penang	70.0
	Straits Trading Co. Ltd.	Butterworth, Penang	60.0
* Thailand	Thailand Smelting & Refining Co. Ltd.	Phuket	25.0
Europe			
Belgium	Métallurgie Hoboken-Overpelt	Hoboken, Antwerp	18.0
East Germany	State-owned	Frieberg/SA	1.5
West Germany	Berzelius Metallhütten-Gesellschaft mbH	Duisburg-Wanheim	3.5
Portugal	Noestano-Nova Empresa Estanifera de Mangualde, S.A.R.L.	Mangualde	0.8
Spain	Metalurgica del Noroeste	Villagarcia de Arosa	3.0
	Minero-Metalurgica del Estaño	Villaverde, Madrid	2.0
	Electrometalurgica del Agueda	Villaralbo	1.0
		Ciudad Rodrigo	1.0
United Kingdom	Capper Pass & Son Ltd.	North Ferriby, Yorkshire	18.0
U.S.S.R.	State-owned	Novosibirsk	30.0
		Podolsk	2.0
		Pitkyaranta	2.0
		Ege-Khaya	5.0
Oceania			
* Australia	Associated Tin Smelters Pty. Ltd.	Alexandria, NSW	10.5
Total			384.1

Source: International Tin Council, with revisions by the Department of Energy, Mines and Resources.
*Producing countries of the Fifth International Tin Agreement.
[1]In process of expansion.

its fuming operation, processing its stockpiled slags and treating some cornish and other concentrates and tin-bearing materials at the Kirby smelter. This operation is expected to continue for at least three more years. Britain produces about 5 200 tonnes of tin from secondary sources.

Tin consumption in 1976 was 13 109 tonnes compared with 12 164 tonnes in 1975. The principal increases were recorded in tinplate, solder and chemicals.

United States. The country is the largest world consumer of tin but records no domestic mine production. All of the U.S. primary tin supply comes from overseas, but about one-fifth of the total tin used in 1976 was reclaimed from scrap. United States consumption of primary and secondary tin in 1976 increased by 16 per cent over the 1975 level to 64 700 tonnes. This was the highest increase recorded in any industrialized country. Major tin uses are tinplate, 31 per cent; solder, 28 per cent; bronze and brass, 14 per cent and chemicals, including tin oxide, 10 per cent.

Current uses of tin in the United States and anticipated changes in consumption are one of the world barometers for the future of tin. Most tinplate (92 per cent) is shipped to can manufacturers. Of all the cans manufactured in 1976, 50 per cent were for beverages, 40 per cent for food and 10 per cent for non-food applications. Of the beverage market containers, 32 per cent were tinplate, 33 per cent tin-free steel (TFS) and 35 per cent aluminum. At present the D&I tinplate cans have a price advantage in the beverage sector, but with higher tin prices, substitutes are expected to gain ground. It is also possible that the use of 98 per cent lead — 2 per cent tin solder on the seams of food cans, could be adversely affected by environmental considerations. If this takes place, it could cause a short-term increase in tin consumption in solder form. In the longer term, however, it would add impetus for diversification away from tinplate cans. In solders, 65 per cent is used in electronics and strong growth may continue in this sector. The use of tin in brass is static and may even decline. Tin chemicals have a bright future in the United States and can be expected to grow at 3 to 4 per cent per year.

The only primary tin smelter is the Texas City plant of Gulf Chemical and Metallurgical Corporation. In 1976, production was about 6 800 tonnes, almost entirely from concentrates imported from Bolivia. Some of the Bolivian concentrates are smelted on a toll basis. In addition to concentrates the smelter processed tin-containing scrap and residues for secondary recovery. This tin smelter has a nominal capacity of 20 000 tonnes per year, but a current effective capacity of about 7 500 tonnes per year.

The Republic of South Africa. Mine production in 1976 was 2 709 tonnes, about the same as in 1975. Modernization completed in 1975 at two main operating companies, Rooiberg Minerals Development Co. Ltd. and Union Tin Mines Ltd., resulted in increased in output in 1976 to 3 710 tonnes and 1 619 tonnes, respectively. The third mine, operated by Zaaiplaats Tin Mining Co. Ltd., produced 303 tonnes.

The Zaaiplaats smelter near Potgietersrus, North of Hohannesburg, smelts three-quarters of the tin mined in South Africa and South West Africa. The latter produces about 700 tonnes of tin in concentrates annually. Zaaiplaats has an annual capacity of about 3 000 tonnes. Production in 1975 was about 2 400 tonnes.

Rwanda. This country produces about 1 200 tonnes annually and ships about 75 per cent of its concentrates for smelting to Belgium.

Zambia like many other African countries, has only very small tin production, estimated at 10 tonnes in 1976. Large deposits of tin and tantalite have been discovered between Batoka and Livingstone in the south of the country which may lead to the opening of new mines in the 1980s.

Burma. Burma produced about 750 tonnes in 1976 compared with 600 tonnes in 1975. Prior to The Second World War, production was 6 000 tonnes annually. The country began a planned program of mineral exploration with foreign assistance. Burma has received $6.5 million in aid from the United Nations Development Program for the period 1974-78 for a variety of projects, including a geological survey, and onshore and offshore exploration for tin and tungsten deposits. The U.S.S.R. and West Germany also contributed to projects aimed at the rehabilitation and expansion of tin-tungsten mines. A loan from West Germany was granted for a substantial increase in output from the Myanma's Heinda mine to take effect sometime in 1976. Such an output, however, was not reflected in the 1976 statistics.

Laos. Tin production in Laos in 1976 was estimated at 576 tonnes, up from the 518 tonnes produced in 1975. It is believed that a large part of the output comes from the Phon Tiou and the Non Sun mines.

India. The country consumes up to 3 000 tonnes of tin annually, but has no recorded production. An important tin find was announced in 1975 in the Bastar area of Madhya Pradesh district. It will be thoroughly investigated and surveyed under a U.N. development program.

Mexico. Domestic mine production in 1976 was estimated at 310 tonnes. Mexico produces metal from imported concentrates for half of its internal consumption which is estimated at 1 600 tonnes. The Estano Elector, Tlalnepantla smelter-refinery has an annual capacity of 1 200 tonnes and will be modernized, using Soviet technology on vacuum refinement of tin.

Belgium. The Hoboken smelter has a rated capacity of 18 000 tonnes per year. However, it produced only 4 068 tonnes of tin in 1976 and 4 562 tonnes in 1975. Imports of concentrates are from Zaire, Rwanda and several small African producers.

Spain. Mine production was 720 tonnes in 1976 and metal production was an estimated 5 369 tonnes, mainly from concentrates imported from Bolivia, Zaire and South Africa, along with smaller quantities from several other countries. Spain originally planned substantial increases in mining for the period from 1974 to 1980. Most of the plans for new mines have been deferred. The Penouta (Orense Province) tin mine originally planned for 1976, with an annual output of 1 500 tonnes of 67 per cent tin concentrate, should be in full production by 1980.

There are a few small tin refineries in Spain but the only smelter of importance is the Villagarcia de Arosa plant of Metalurgica del Noroeste where capacity is now being increased from 3 000 tonnes a year to approximately 6 500 to 7 000 tonnes a year. The new plant is being built by Lurgi Gesellschaft of Frankfurt, West Germany.

West Germany. Metallgesellschaft A.G.'s Berzelius smelter in Duisburg that has a capacity of 3 600 tonnes, produced over 3 000 tonnes of tin in 1976 of which approximately 1 400 tonnes was primary tin. Investments are continuing in new "low-pollution" secondary tin recovery processes in Germany with the objective of significantly reducing reliance on tin imports.

The People's Republic of China. China is a significant world producer and exporter of tin. Production has been estimated at 20 000 tonnes annually. Output is primarily from the lode deposits in the Kochui district in Yunnan and the placer deposits of the Fuhochung area in Kwangsi. In 1975 China exported about 12 500 tonnes of tin, but in 1976 exports decreased significantly to approximately 6 450 tonnes.

Latest reports indicate that China is not able to boost tin output as much as expected. A major new tinplate facility was completed in 1976 and will take increasing amounts of tin previously earmarked for export. Furthermore, with rising domestic demand, it is doubtful that exports will ever exceed the 4 000 to 6 000-tonne-a-year level in the foreseeable future.

Soviet Union. U.S.S.R. tin mine production is currently estimated at between 20 000 and 25 000 tonnes per year and until two years ago a further 4 000 to 5 000 tonnes were imported annually. Imports of tin metal increased significantly in 1975 to 9 654 tonnes, and to 9 440 tonnes in 1976. This may be partially due to a fundamental change in demand, as the Soviet Union is known to have increased production of consumer goods that would tend to reflect on tin consumption for tinplate production, and partially the result of a stockpiling program. Based on the above data it seems that apparent consumption now exceeds 30 000 tonnes a year. About 25 per cent is utilized in tinplate and about 70 per cent in alloys, including solders. Exports to other Council for Mutual Economic Assistance (COMECON) countries increased. An American Iron and Steel Institute mission to the U.S.S.R. (*Tin International* Feb. 1975) noted that the methods in tin plating are inefficient and result in excessive tin coatings.

Western sources report that tin remains a high-priority metal in the Soviet exploration and development plans and that by 1980 production could rise to 30 000 to 35 000 tonnes a year. By that time, however, consumption is again expected to be ahead of production by some 10 000 tonnes a year.

The international tin agreements

Tin is the only metal for which there is formal cooperation between producer and consumer interests and among governments to rationalize problems of supply and demand and attenuate, to a certain extent, excessive price variations. The large mine producers of tin are developing countries with little consumption, and the largest consumers are the major industrial countries. A common interest in market stability in the postwar period led first to a study group and then to the First International Tin Agreement in 1956 under the auspices of the United Nations. The International Tin Council was formed to implement this agreement.

The First International Tin Agreement was in force from July 1, 1956 to June 30, 1961 and the second from July 1, 1961 to June 30, 1966. The third and fourth international tin agreements came into force on July 1, 1966 and July 1, 1971, respectively. The current agreement expired on June 30, 1976. Negotiations leading to the implementation of the next five-year international agreement were held in Geneva in May 1975.

The main objective of The International Tin Council is the consideration of short-term problems of supply and demand and pricing. Decisions that affect supply and price, however, are made with regard to long-term trends. Consumer and producer members have an equal number of votes in the governing body, The International Tin Council. Canada is a signatory to the fourth agreement and, in proportion to its consumption, it had 42 out of the total of 1 000 votes allocated to consumers. The 22 consumer members and seven producer members accounted for 85.7 per cent of recorded world consumption in 1976. The total does not include U.S.S.R. consumption, as its data are not available, even though the U.S.S.R. is a member country. The United States was the main nonmember country among Western consuming countries until July 1, 1976 when it decided to join the Fifth Agreement as a first-time member.

Producer members are Australia, Bolivia, Indonesia, Malaysia, Nigeria, Thailand and The Republic of Zaire. Counted together, producer and consumer members of the Council account for 89 per cent of the noncommunist production of tin in concentrate, with the seven producer members alone accounting for 86 per cent.

Members of The International Tin Council established a buffer stock which at the beginning of the Fourth Agreement had direct financial resources equivalent to about 20 000 tonnes of tin, but due to continuous increases in the tin price these resources were only equivalent to about 12 500 tonnes at the end of 1975. In addition to the above, the Council has the authority to

Table 7. Price ranges in tin agreements

Period of operation	Floor Price	Sector Lower	Sector Middle	Sector Upper	Ceiling Price
			(£/long ton)		
1 July 1956-22 Mar. 1957	640	640-720	720-800	800-880	880
22 Mar. 1957-12 Jan. 1962	730	730-780	780-830	830-880	880
12 Jan. 1962-4 Dec. 1963	790	790-850	850-910	910-965	965
4 Dec. 1963-12 Nov. 1964	850	850-900	900-950	950-1000	1000
12 Nov. 1964-6 July 1966	1000	1000-1050	1050-1150	1150-1200	1200
6 July 1966-22 Nov. 1967	1100	1100-1200	1200-1300	1300-1400	1400
22 Nov. 1967-16 Jan. 1968	1283	1283-1400	1400-1516	1516-1633	1633
16 Jan. 1968-2 Jan. 1970	1280	1280-1400	1400-1515	1515-1630	1630
			(£/metric ton)		
2 Jan. 1970-21 Oct. 1970	1260	1260-1380	1380-1490	1490-1605	1605
21 Oct. 1970-4 July 1972	1350	1350-1460	1460-1540	1540-1650	1650
			(M$/picul)		
4 July 1972-21 Sept. 1973	583	583-633	633-668	668-718	718
21 Sept. 1973-30 May 1974	635	635-675	675-720	720-760	760
30 May 1974-31 Jan. 1975	850	850-940	940-1010	1010-1050	1050
31 Jan. 1975-12 March 1976	900	900-980	980-1040	1040-1100	1100
12 March 1976-7 May 1976	950	950-1000	1000-1050	1050-1100	1100
7 May 1976-	1000	1000-1065	1065-1135	1135-1200	1200

In the light of changes in exchange rates occasionned by the "floating" of the £ Sterling, the price range has been expressed in terms of the ex-works price of tin on the Penang market in Malaysian dollars per picul since 4 July 1972.

borrow on the commercial markets, using tin held by the buffer stock as collateral.

The operation of the stock, to which until recently only producer members contributed, is vested in a manager appointed by the Tin Council, and responsible to the Executive Chairman of the Council. The ranges of permissible prices are set by the Tin Council and within this framework the manager of the buffer stock may use discretionary judgment to buy or sell tin metal, but not concentrates, on major markets to modify price fluctuations and ease supply problems.

The Council may impose export controls to curtail metal supply if tin in the buffer stock exceeds 10 000 tonnes and other conditions appear to warrant such action. Financial resources of the buffer stock were signficiantly bolstered by voluntary contributions from the Netherlands since 1971 and France since 1973 in proportion to their consumption and votes on the Council.

The buffer stock manager operates within price ranges designated as the lower, middle, and upper sector as shown in Table 7. Under the first three agreements, the buffer stock manager was directed to buy only in the lowermost sector and sell only in the uppermost sector with no action in the middle sector except under special instruction, which was rarely granted. Under the Fourth Agreement, however, the buffer stock operations were more effective, since the manager was given authority to both buy and sell in the lower and upper sectors as long as he remains a net buyer in the lower sector and net seller in the upper sector. The manager was also given permission to operate temporarily in the middle sector under special provisions.

Export controls were invoked on a number of occasions, most recently between January 19, 1973 and September 30, 1973 and again between April 18, 1975 and April 18, 1976. Export quotas for the producer members of the International Tin Council are set in proportion to historical export statistics for selected preceding quarters. The export controls are established on a quarterly basis. Once a maximum permissible level is set for a given quarter it cannot be lowered, but controls can be lifted at any time. Controls can be tightened in each successive quarter if market deterioration warrants this action. For each occasion, special full sessions of the International Tin Council must be held. External borrowing is also approved at full sessions of the Council. Before setting the total export quota, the Council examines estimates of production and consumption and takes into account the quantity of tin metal and cash held in the buffer stock, the quantity, availability and probable trend of other stocks, including General Service Administration (GSA) disposals, the trade in tin, the current price of tin metal and other relevant factors.

The Fifth International Tin Agreement

The Fourth International Tin Agreement expired on July 1, 1976. The United Nations Conference on Trade and Development (UNCTAD) conference, in which Canada participated, that established the text of the Fifth International Agreement was held in Geneva from May 20 to June 21, 1975.

The new Agreement was open for provisional ratification at the United Nations headquarters in New York from July 1, 1975 to April 30, 1976 by parties to the Fourth International Tin Agreement and by governments invited to the United Nations Tin Conference in 1975. It then enters in force on a provisional basis for one year (July 1, 1976 to June 30, 1977) until all necessary final ratification documents are submitted.

The Fifth Agreement enters into force when ratified by at least six producing countries holding, together, at least 950 of the 1 000 votes allocated to the seven producers, and by at least nine consuming countries holding, together, at least 300 of the 1 000 votes allocated to the 28 consuming countries. The ratification system for the producers could be construed as a weakness of the new agreement since any one of the seven major producers may prevent its implementation.

The Fifth Agreement is designed primarily to prevent excessive fluctuations in the price of tin, to help increase export earnings from tin and to secure an adequate supply of tin at prices fair to consumers and remunerative to producers. The participating countries also recognized that the agreement is in the spirit of the new international economic order.

The Fifth Agreement, like previous international tin agreements, incorporates two main operational mechanisms: the use of a buffer stock and the application of export controls when necessary in order to adjust supply to demand. The operation of the buffer stock is related to a floor and ceiling price being divided into three sectors. The floor and ceiling prices are to be expressed in Malaysian ringgit or in any other currency the International Tin Council may decide. The initial floor and ceiling prices under the Fifth Agreement will be those in force on the termination of the Fourth Agreement.

Contributions by producing countries to the buffer stock are required to amount to the equivalent of 20 000 tonnes in cash, tin metal or a combination of both, as determined by the council. The equivalent of 7 500 tonnes is due on the entry into force of the agreement, and the remainder as, and when, determined by the council. An important change introduced as regards to valuation of tin in connection with contribution to the buffer stock is that contributions to the buffer stock made in cash after the entry into force of the agreement will be made at the floor price prevailing at that time and not, as under the Fourth Agreement, at the floor price on the entry into force of the agreement. This will reduce any erosion of the authorized size of the buffer stock which might otherwise result from increases in the floor price during the life of the agreement.

The Fifth Agreement provides for additional contributions to the buffer stock over and above those required from producing countries as in the Fourth Agreement, contributions may be made by any country invited to the conference; such voluntary contributions are made under the Fourth Agreement by France and the Netherlands. However, a major innovation in the Fifth Agreement is that an amount of up to the equivalent of 20 000 tonnes of tin metal is an implied overall target for contributions from the consuming countries participating in the agreement. After the agreement has been in operation for two and a half years, the council must review the results obtained in regard to these additional contributions. In the light of its review it may decide that a conference be convened within six months to renegotiate the Agreement.

As under the Fourth Agreement, the Fifth Agreement provides that the council may also borrow for the purposes of the buffer stock on the security of the tin it holds. Furthermore, in the event of any other financial resources becoming available to the council (for example, directly from international financial organizations), the council may modify the arrangements concerning the size and financing of the buffer stock.

The Council has the task of keeping under review and studying the tin situation, including specified factors. The council may, at any session, review the price range and, in so doing, must take these specified factors into account. An innovation in the Fifth Agreement is the specific mention of production costs among those aspects which are to be the subject of continuing study.

A new provision allows the council, in the event of shortage, to make recommendations to producing countries on appropriate measures, not inconsistent with other international agreement on trade, to ensure that preference as regards the supply of available tin is given to consuming countries participating in the agreement. These provisions are designed to be a counterpart to the provisions for export control in times of actual or expected surplus of tin on international markets.

The following occurred from the inception of the Fifth Agreement on July 1, 1976:

- The agreement went into force provisionally, with all the main producers ratifying it except Bolivia.
- The United States joined for the first time and was assigned 275 votes out of the consumers' total of 1 000 votes.
- Canada joined again and pledged to make a voluntary contribution to the buffer stock. Canada's votes were reduced to 32 out of 1 000 consumer votes.

- Besides France and the Netherlands that renewed their voluntary contributions, Belgium, the United Kingdom and Denmark made pledges of contributions to the buffer stock.
- In late 1976 and early 1977, Bolivia expressed major dissatisfaction with the system of determining price ranges governing the operation of the buffer stock and notified the council that unless major changes are made, Bolivia may not ratify the Fifth Agreement.
- Bolivia's action may precipitate the end of the Fifth International Tin Agreement on June 30, 1977.

General Service Administration (GSA) stockpile

An important stockpile of tin in the world is that held by the United States in its stockpile of Strategic and Critical Materials. This stockpile held about 348 500 long tons of tin in 1962, before disposals of that tin deemed to be in excess of strategic requirements began. By July 1, 1968, when commercial U.S. stockpile sales were suspended, these stocks were down to 257 524 long tons. Minor tin sales continued between 1968 and 1973 under the program of the United States Agency of International Development (AID). In June 1973 commercial sales were resumed and the level of sales surged.

The stockpile objective was raised on March 28, 1969 from 200 000 to 232 000 long tons. The original tin stockpile authorization was not repealed in 1969 when congress raised the objective to 232 000 long tons, and in August, 1974 the GSA officially announced that the extra 32 000 long tons would be available for disposal, increasing the total to 49 897 long tons. On October 1st, 1976 the Federal Preparedness Agency (FPA) set a new stockpile goal of 33 021 long tons, a reduction of 8 129 long tons from the prior objective. In February 1977 President Carter put a moratorium on sales from the GSA stockpile. During 1976 GSA sold 3 546 long tons of tin, compared with 569 long tons in 1975 and 23 137 long tons in 1974.

Uses

Tin metal is unequalled as a protective, nontoxic hygienic coating on steel. The manufacture of tinplate represents the largest market for tin. Approximately 85 per cent of tinplate is used by the can-making industry. Available world data indicate that 78 600 tonnes of tin were used in 1976 for the production of 13.4 million tonnes of tinplate, compared with 72 200 tonnes used to produce 12.0 million tonnes in 1975. The tin coating on steel varies with the product mix of tinplate plants, from 0.25 pounds per base box (5.6g/m^2) for electrolytic tinplate, up to 1.25 pounds (28 g/m^2) for the hot dip process. Tinplate is sold by the base box (31 360 square inches). Expressed another way, the tin content is typically about 0.6 per cent.

Tin International reports in its January 1976 issue that at the end of 1975, 108 electrolytic tinning lines were in operation in the world, which include all 33 important producing countries other than the U.S.S.R. and the People's Republic of China. A further 16 dual lines are installed to produce either electrolytic tinplate or "tin-free steel". Total finishing capacity is some 20 million tonnes, of which almost 98 per cent is now electrolytic. Five more high-capacity electrolytic tinplate lines were scheduled for commissioning in 1977.

The technology of can-making is changing, with better and more economic uses being made of coiled tinplate. Other developments include the use of double-reduced tinplate and of jet soldering techniques for can side-seams. A tin coat also imparts an inherent lubricity of tinplate, an important characteristic for the recently introduced deep-drawn and wall-ironed can-making process (D&I). Seamless cans could compete in the beer and beverage can market in which chrome-plated steel (TFS) or aluminum have already acquired a strong foothold, increasingly replacing glass containers. Crown Cork & Seal Corporation in the United States was the first to achieve commercial production of one-piece D&I tinplate cans in 1971; in 1972 American Can Company began production of a similar line at Edison, New Jersey. In Britain, The Metal Box Company started commercial production of D&I cans in 1973. There is currently no substitute for tinplate in most container applications involving food preserving and the expansion of this market will continue, particularly in less-developed countries. Despite yearly increases in absolute quantities of containers, the utilization of tin in tinplate has remained static in the past few years mainly because of thinner, more economical applications of tin coatings. In the United States the tinplate industry, for example, utilized 5.176 kilograms of tin per tonne of tinplate in 1971, 4.849 kg in 1972 and 4.504 kg in 1973. In 1974 and 1975 the utilization was up to 4.612 kg and 5.011 kg per tonne of tinplate respectively. This can be compared with the utilization of 5.954 kg per tonne of tinplate for world average in 1974 and 6.016 kg in 1975. While most processed food products are now packed in cans manufactured from electrolytic tinplate, demand for hot-dipped (HD) tinplate material for canning highly corrosive foods such as fish remains strong in some countries. In the developed countries, HD tinplate is being increasingly replaced by electrolytic, particularly bi-differential tinplate, which carries a heavier coating on one face than on the other.

After tinplate, solders are the second-largest tonnage users of tin; estimated at 24.5 per cent in the United States, 37.1 per cent in Japan and 14.7 per cent in West Germany in 1975.

The common solder used, in side seams of tin cans for example, consists of 60 to 70 per cent tin. For soldering galvanized metal (e.g. in the automotive industry) solders with a 50 to 60 per cent tin content are commonly used since they possess the best "wetting" characteristics.

Uses for tin solder (6063 per cent Sn) in the electronics industry are growing rapidly; tin remains unchallenged as the means for interconnecting components, giving utmost reliability. New applications are the mass production of "tailor-made" preforms based on discs and washers punched from foil, and the use of a tin-lead powder and flux mixture that fuses when heat is applied. Tin and tin-rich coatings are also widely used to ensure highest solderability.

Soft solders are used to join side seams of cans (2-3 per cent Sn) and as lead-rich, body-filling solders (2 per cent Sn) in the automotive industry. Automobile radiator cores are another important application. This market could run into some stiff competition with the announcement by some large European radiator manufacturers that they have solved the problems of mass-producing aluminum radiators. Use of solders in plumbing is important, but is not increasing in proportion to gains in the construction industry because of the increased use of PVC (polyvinyl Chloride) plastics. In 1974 the average ratio of tin to lead used in solders by U.S. industry was 1 to 3.5.

Tin is being increasingly used with silver in low-temperature soldering applications. Comparisons of the mechanical properties of 95 per cent tin — 5 per cent silver solders, with 80 per cent lead — 20 per cent tin solders, show that both the ultimate tensile strength and the shear strength of the silver-containing solders are approximately twice that of lead-tin products. The silver solders are also about 30 per cent harder, and elongate less than one-fourth as much as the lead-tin solders when the end products have to withstand stress, impact or heat. Also, tin-silver solders are non-toxic, which is an essential consideration for joints that come in contact with food or drink. Applications today vary from plumbing, heating, refrigeration and air conditioning, to food servicing and processing utensils, holloware and the electronics industry. Because of the non-toxicity of tin-silver solders, this application could result in significant increases in tin and silver usage in countries where the laws on toxicity might be made more stringent.

The alloy applications of tin have a long tradition. Babbitt (usually 50 to 91 per cent tin) and white metal alloys (e.g., 10 to 15 per cent tin and 4 to 12 per cent antimony) are used in bearings and so are aluminum-tin alloys, which have a higher fatigue strength. Newer bearing materials include chromium- and beryllium-inoculated, tin-base alloys offering markedly improved mechanical properties. Copper-tin alloys such as bronze and gunmetal (up to 12 per cent Sn) have an average tin content of about 6 per cent and account for about 7 per cent of the world primary tin consumption; or for about 12 000 tonnes of primary tin, plus some 28 000 tonnes of secondary tin. The gunmetals contain copper, tin and zinc, and sometimes lead, to improve machinability. Bells are still being cast in "bell metal" (77 per cent copper, 23 per cent tin). In January 1975 the eight-ton Liberty Bell was cast by a renowned Dutch firm. It was shipped to Philadelphia's Independence Hall for United States bicentennial celebrations and then transferred permanently to Washington.

Continuous casting of standard shapes has reduced fabrication cost and caused renewed interest in bronze as an engineering material. A heat-treatable tin-bronze has now been developed, giving added strength.

Titanium-tin alloys bearing 2 to 11 per cent tin are used increasingly in the aerospace industry, especially in supersonic jets. The British-French Concorde is among the aircraft utilizing these alloys. Terneplate, an alloy of 80-88 per cent lead and 12-20 per cent tin, has a three-century tradition as a most durable roofing material, and shows signs of revival in the United States. Other applications for terneplate are in automotive oil filters and some fixtures, and in critical body parts, for example the undersides of electric golf carts. A possible future use with large tonnage potential would be as a replacement of copper in radiator cores. A product introduced by Hoesch A.G. in West Germany in 1973 is Galvo-Terne. It is a cold-rolled sheet, electrolytically coated with an 88 per cent lead — 12 per cent tin alloy, offering attractions for corrosion-resistant car parts (gasoline tanks). It is resistant to a number of chemicals, suggesting potential uses in chemical plant applications.

Pewter has again become popular; for instance, pewter plate and beaker castings commemorated the 1972 Munich Olympics. Modern methods of making pewterware from rolled sheet have recently been introduced. Pewter is pure tin that has been hardened by the addition of copper and antimony, representative compositions range from 91 per cent tin, 2 per cent copper and 7 per cent antimony to 95 per cent tin, 1 per cent copper, and 4 per cent antimony. Lately, the Association of British Pewter Craftsmen drew up plans for guaranteeing a minimum of 90 per cent tin in British pewter articles. Some pewters are lead-free but many pewters favour the addition of up to 0.5 per cent lead. Total world consumption of tin for the manufacture of pewter is now estimated to approach 5 000 tonnes a year.

Fusible alloys of tin, bismuth, lead, cadmium and, sometimes indium, are used in safety devices such as heat fuses. Diecasting alloys of tin, antimony and copper have applications in the production of jewellery.

Tin is widely used as a minor alloying agent in other metals; for example, alloy AP (antipollution) bronze is a corrosion-resistant, copper-tin-aluminum alloy for condenser tubes in power stations operating in polluted waters. Tin accounts for 5.5 to 9.0 per cent of this alloy. Tin is a constituent in superconductive alloys such as intermetallic Nv_3Sn. Tin is also used in special protective coatings, particularly as a tin-nickel alloy electroplate which has excellent corrosion resistance, high hardness and the power of retaining an oil film.

Lead-calcium-tin alloys are now being introduced in battery manufacturing, a market long served almost exclusively by antimonial lead. The tin content in this alloy is up to 1.3 per cent. There are forecasts that such maintenance-free, lead-acid batteries may capture up to one-third of the U.S. battery market by 1980.

Table 8. Monthly tin prices, 1976

	London Metal Exchange			New York			Penang		
	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Average
	Cash -£ per tonne			Prompt -¢ per lb			Ex-works -$M per picul		
Jan.	3 136.0	3 052.5	3 074.2	318.0	308.5	309.7	982.0	957.0	960.2
Feb.	3 291.5	3 131.5	3 205.4	336.0	316.0	324.6	1 047.0	976.0	1 003.0
Mar.	3 740.0	3 269.0	3 552.2	351.8	336.5	345.7	1 085.0	1 036.0	1 064.8
Apr.	3 935.0	3 696.0	3 848.6	357.0	344.8	352.1	1 099.0	1 061.0	1 084.6
May	4 327.0	3 875.0	4 120.4	385.3	257.3	370.5	1 190.0	1 099.3	1 144.7
June	4 577.0	4 312.0	4 410.4	390.3	376.5	381.5	1 197.1	1 159.0	1 172.4
July	4 905.0	4 538.5	4 760.4	430.0	398.3	416.3	1 320.0	1 220.4	1 263.6
Aug.	4 771.0	4 407.0	4 534.6	418.0	386.3	398.2	1 251.5	1 158.8	1 195.0
Sept.	4 804.0	4 466.0	4 598.8	396.0	384.0	389.1	1 198.0	1 161.0	1 178.2
Oct.	5 067.5	4 707.5	4 844.2	406.0	387.0	393.6	1 230.0	1 180.0	1 195.7
Nov.	5 037.5	4 862.5	4 958.3	410.8	390.0	400.5	1 250.0	1 190.0	1 221.3
Dec.	5 252.5	4 907.5	5 001.1	430.5	403.3	410.7	1 318.0	1 228.0	1 250.8

Source: International Tin Council, Monthly Statistical Bulletin.

A relatively new application is the use of small quantities of tin (approximately 0.1 per cent) in cast iron for engine blocks, crankshafts and rear-axle assemblies. Adding tin assures a uniformly hard, wear-resistant and thermally stable perlitic structure in the castings. Current consumption for this usage is estimated at 1 000 tonnes a year. Tin has also an application in powder metallurgy, primarily for sintered bronze bearings (sealed, self-lubricating). A new application is powder-sintered, bronze-teflon bearings. Tin plus copper is replacing other metallic additions to iron powders to improve the quality of conventional sintered iron alloys, but only a substantial reduction in the price of tin powder could lead to a large market expansion for such products. Some encouragement of this field is provided by recent experiments in West Germany on the use of water-atomized powder produced directly from tinplate scrap.

Pure tin is used in collapsible tubes, especially for pharmaceutical products. Tin is used in conjunction with the manufacture of glass, through the "float process", in which a continuous ribbon of glass floats along the surface of a bath of molten pure tin. The process was introduced by Pilkington Brothers (U.K.) in 1959 and has now completely superceded the plate process for making high-quality flat glass.

Tin is also marketed as tin oxide for polishing applications; a newer use of tin oxide is in the manufacture of conductive glass and glass resistors.

Tin is used widely in organotin compounds and

Table 9. Forecast of tin metal balance (exclusive of stock releases)

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
	(thousands of tonnes)											
Western World demand												
1% growth*	199	173	190	195	197	199	201	203	205	207	209	211
2% growth*	199	173	190	195	199	203	207	211	215	220	224	228
Adjust for Net Sino-Soviet Demand	(-5)	(-4)	3	3	5	5	10	10	10	10	10	10
Net Western World demand												
1% growth	194	169	193	198	202	204	211	213	215	217	219	221
2% growth	194	169	193	198	204	208	217	221	225	230	234	238
Western World supply	177	176	179	180	183	190	200	215	230	240	235**	235**
Balance												
Surplus (Deficit)												
1% growth	(17)	7	(15)	(18)	(19)	(14)	(11)	2	15	23	6	9
2% growth	(17)	7	(15)	(18)	(21)	(18)	(17)	(6)	5	10	1	(3)

*Base 195 000 tonnes in 1977.
**Slow adjustment of mine output in response to oversupply.

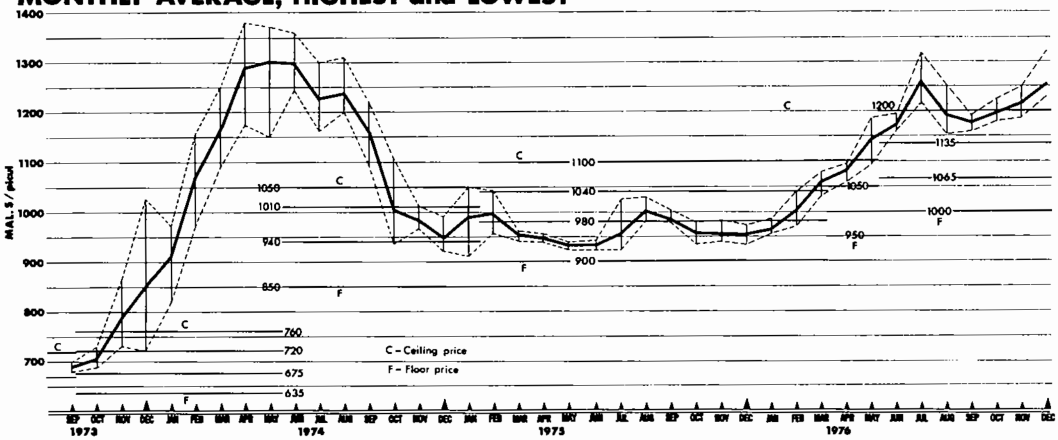
inorganic tin compounds. Chemicals, however, account for consumption of 5 000 to 10 000 tonnes, much of which comes from secondary tin. Growth potential from this modest base is excellent. The main uses of organotins are: as dioctyltin stabilizers for PVC, as triphenyltin fungicides in agriculature, and as tributyltin in industrial biocides and disinfectants. Inorganic compounds stannous chloride and stannous sulphate, as well as sodium stannate and potassium stannate, are used as electrolytes in the tinplating process. The chloride also stabilizes the colour and perfume of soap. Stannic oxide is an opacifier in enamels. Stannic chloride is a basic chemical in the manufacture of the organotin compounds. Under development is the use of organotin chemicals as biocidal compounds to combat tropical disease; for example, schistosomiasis (blood flukes), by eliminating the main carrier, the water snail.

Outlook

There has been a drastic decline in world mine production of tin between 1972 and 1976, with a decrease from a peak of 195 300 tonnes to 175 000 tonnes. A small improvement in output is foreseen for 1977, with production again increasing to the 180 000-tonne-per-year level. However, there is no prospect of further significant increases over the next few years, since major producers such as Malaysia, Bolivia, Indonesia, Thailand and Australia have limited capability to increase output on short notice.

Statistical supply deficits occurred in the past, and these were mainly counteracted by releases from the United States stockpile. The last serious supply deficits of 1973 and 1974 were covered by a release of some 40 500 tonnes. This was followed by an over-supply period from late 1974 to early 1976, when export controls and

TIN PRICE PENANG EX-WORKS: MONTHLY AVERAGE, HIGHEST and LOWEST



Source: International Tin Council
Note: Indicative price ranges of the Buffer Stock also shown.

Tin chemicals are used as highly efficient catalysts in polyurethane foam technology and in the construction industry, and as catalysts in silicone elastomers, also known as semiplastic sealants; a rapidly expanding application. Organotins have outstanding stabilizing properties for the production of PVC compounds and roofing materials, as well as for products used in the packaging industry.

The high-purity tin produced in Canada by Cominco, 59 grade (5-9's) (99.999 per cent) and 69 grade (6-9's) (99.99 per cent) is used mostly in metallic form in the electronics industry. Some is used to produce semiconductors, such as a tin-lead telluride for advanced solid-state radiation detection devices. Tin is reclaimed by M.&T. Products of Canada Limited in the form of potassium stannate and is used directly in electroplating.

substantial purchases by the buffer stock manager of the International Tin Council remedied the situation. The rapid turnaround in demand in 1976 was not only in response to real consumption, but to a slight shift in the attitude of consumers, who were once again willing to carry larger inventories. Thus the release during the latter part of 1976 of some 19 200 tonnes of tin accumulated by the buffer stock manager was a welcome addition to supply.

The tight supply situation caused prices to remain very strong during the latter part of 1976 and early 1977. This turn of events was forecast in our published review for 1975. Tin shortage, however, continues to dominate the scene in early 1977 and large deficits loom ahead for 1977 and thereafter. The tight supply situation may last three to four years, and will take place even if the demand growth is low, i.e., 1 per cent a year. The deficit could be more pronounced if an apparent growth rate in demand of 3 to 4 per cent materializes, as some experts believe. Prices will continue to be very strong, and very unstable. Timely stockpile releases, from the United States stockpile, starting not later than the second half of 1977 are crucial and there is some valid apprehension that the U.S. Congress may not be able to act as fast as market developments warrant. Releases may have to wait until a review of the entire U.S. stockpile program is completed, which may not happen before 1978.

As of the time of writing, i.e., June 1977, prices are, and have been for the past few months, consistently above the buffer stock manager's ceiling of 1 325 Malaysian dollars per picul. There is a very real possibility that a price explosion may send the free market price to a level of about 2 000 Malaysian dollars per picul in the next 12 months.

Runaway prices are not in the long-term interest of either producers or consumers. Excessive prices will most certainly stimulate new developments in the mining industry, but significant results will not be evident until sometime after 1980. On the other hand demand-pull price behaviour (i.e., runaway prices) in the 1977-79 period could trigger irreversible substitution, particularly in the tinplate industry. The net result of such developments would be a demand fall-off, resulting in a significant oversupply of tin sometime in the early 1980s.

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Tin in ores and concentrates	free	free	free	free
33507-1	Tin oxides	free	15%	25%	free
33910-1	Collapsible tubes of tin or lead coated with tin	10%	17½%	30%	10%
34200-1	Phosphor tin	5%	7½%	10%	5%
34300-1	Tin in blocks, pigs, bars or granular form	free	free	free	free
34400-1	Tin strip waste and tin foil	free	free	free	free
38203-1	Sheet or strip, iron or steel, corrugated or not, coated with tin	10%	12½%	25%	8%
43220-1	Manufactures of tinplate	15%	17½%	30%	11½%

United States

Item No.		On or after January 1, 1975
601.48	Tin ore and black oxide of tin	free
608.91	Tinplate and tin-coated sheets, valued at not over 10¢ per pound	8%
608.92	Tinplate and tin-coated sheets, valued at over 10¢ per pound	0.8¢ per lb
622.02	Unwrought tin other than alloys of tin	free
622.04	Unwrought tin, alloys of tin	free
622.10	Tin waste and scrap	free
622.15	Tin plates, sheets and strips, not clad	6%
622.17	Tin plates, sheets and strips, clad	12%
622.20	Tin wire, not metal-coated or plated	6%
622.22	Tin wire, metal-coated or plated	6%
622.25	Tin bars, rods, angles, shapes and sections	6%
622.40	Tin pipes, tubes and blanks	6%
644.15	Tin foil	17.5%

Sources: For Canada, the Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976) TC Publications 749.

Titanium and Titanium Dioxide

ALBERT BOUCHARD

The titanium pigment (TiO_2) industry consumes more than 90 per cent of the world's production of titanium minerals. Ilmenite ($FeOTiO_2$) accounts for about 90 per cent of this production and rutile (TiO_2), 10 per cent. In 1976 world production of ilmenite is estimated at 3 578 000 tonnes,* principally from Australia, the United States, Canada and Norway. World production of rutile is estimated at 337 473 tonnes, chiefly from Australia. During recent years, the pigment market has been affected by the world economic recession; however, towards the end of 1975 and during 1976, demand increased.

Titanium dioxide is produced by two different methods, the sulphate or the chloride processes, depending on the material. In the sulphate process, an ilmenite concentrate containing between 30 and 50 per cent impurities, is digested in sulphuric acid. About three to four tonnes of sulphuric acid are required per tonne of titanium dioxide product. This procedure produces a large quantity of very polluting effluent which is a mixture of weak sulphuric acid and crystallized ferric sulphate. Most titanium dioxide producing countries have strict requirements regarding pollution, and although interested companies must find effective methods to avoid it, the cost of the presently known anti-pollution techniques are high. The chlorine process has an important advantage over the sulphate process, because the quantity of waste produced is low and the chlorine used for solution is recyclable. However, the chlorine process is limited to use with rutile, a serious disadvantage, since the world reserves of rutile are small compared to ilmenite.

A number of studies are being undertaken to find an answer to these problems and two new techniques are presently in use; the production of synthetic rutile, which is then processed in the same way as natural rutile by the chloride route, and a new chloride process, which is applicable to ilmenite concentrate. The present overall tendency of pigment producers, as a response to anti-pollution demands, is to replace the sulphate process with the chloride process.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Canada

The Quebec Iron and Titanium Corporation is the only company in Canada that mines and processes ilmenite ore. This company is under U.S. ownership, with two-thirds owned by Kennecott Copper Corporation and one-third by the New Jersey Zinc Company. The ore is mined by open-pit methods in the Lac Tio — Lac Allard area of eastern Quebec, and is crushed on-site to less than 7.6 cm. The crushed ore is shipped 43 km by rail to Havre St.-Pierre where it is loaded on ore carriers which transport it via the St. Lawrence Seaway to the company's plant and smelter at Sorel, near Montreal. The ilmenite, which has an average content of 86 per cent iron oxides and titanium oxides, is upgraded to a mean content of 93 per cent, using heavy media separation, spirals and cyclones. The upgraded product is calcined in a rotary kiln to lower the sulphur content, and after cooling is mixed with powdered anthracite and melted in an electric arc furnace. The fusion products are titanium slag, called *Sorelslag,* with a 70 to 72 per cent TiO_2 content, and pig iron with a low manganese content, called *Sorelmetal.* Sorelmetal is further processed to meet customer requirements. The titanium slag is used for the production of TiO_2 pigment via the sulphate process. The pig iron is used chiefly in the manufacture of ductile iron, but also in powder metallurgy. A third product, called *Sorelflux,* is also sold and marketed by the company. This is a raw ilmenite ore with a granularity between 6.4 and 38.0 mm, which is used as a metallurgical flux in electric furnaces.

During the year there has been a strong world demand for the titanium slag produced by Quebec Iron and Titanium Corporation which, in fact, has been substantially larger than production. The chief reason for the demand for Sorelslag on the international market stems from the fact that the production of pigment is less polluting when titanium slag is used as a starting material rather than ilmenite, whose content is between 40 and 50 per cent TiO_2. However, the stockpile of Sorelmetal is very high, a potential problem situation which had already begun to emerge towards the end of 1975 when the accumulated stockpile amounted to about two months' production. The situation can be expected to worsen during 1976, with the stockpile accumulation reaching 386 100 tonnes by the beginning of September. The inventory excess has resulted from the severe economic recession of 1974-75 and the slow recovery in demand for Sorelmetal.

In 1976 Quebec Iron and Titanium processed 2 115 230 tonnes of ilmenite to produce 814 040 tonnes of titanium slag and 551 078 tonnes of pig iron. This is equivalent to a production increase of close to 10 per cent, compared with 1975. Most of the titanium slag, or Sorelslag, is exported to the United Kingdom, Western Europe, and the United States. About 12 per cent of the production is sold on the Canadian market to two pigment producers — Canadian Titanium Pigments Limited of Varennes in Quebec, a subsidiary of N L Industries Inc., of the United States; and Tioxide of Canada Limited of Tracy, Quebec, a subsidiary of British Titan Products Ltd. of England. Both producers use the sulphate process, and have a combined production capacity of approximately 69 000 tonnes a year. The Canadian pigment market can handle about 55 000 tonnes a year, with the consumption distributed as follows: paints (65 per cent), paper (15 to 20 per cent), other uses, including plastic and rubber, (15 to 20 per cent). The TiO_2 pigment market is dependent on the paint market, and is thus subject to seasonal variations with the strongest demand in spring and fall.

Table 1. Canadian titanium production and trade, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production (shipments)				
Titanium dioxide slag	. .	55 811 738	. .	74 410 000
Imports				
Titanium dioxide, pure				
United States	1 836	1 675 000	3 643	3 444 000
United Kingdom	494	433 000	647	584 000
West Germany	120	117 000	589	598 000
Australia	17	6 000	—	—
Belgium and Luxembourg	—	—	86	66 000
France	—	—	—	—
Total	2 467	2 231 000	4 965	4 691 000
Titanium dioxide, extended				
United Kingdom	113	119 000	113	124 000
United States	45	91 000	100	157 000
West Germany	62	44 000	57	38 000
Czechoslovakia	20	10 000	5	21 000
Switzerland	1	3 000	2	6 000
Total	241	267 000	277	346 000
Titanium metal				
United States	362	4 978 000	431	5 894 000
United Kingdom	36	1 118 000	3	74 000
Japan	5	58 000	5	77 000
Other Countries	1	13 000	1	31 000
Total	404	6 167 000	440	6 076 000
Export[1] to the United States				
Titanium metal, unwrought, including scrap and rejects	139	230 452	142[2]	137 713[2]
Titanium metal, unwrought	160	1 879 947	106[2]	996 074[2]
Titanium dioxide	9 045	6 603 515	9 661[2]	8 034[2]

Source: Statistics Canada.
[1]From *Imports for Consumption*, Report FT 135, U.S. Dept. of Commerce. Canadian export statistics do not provide separate categories. [2]11 months in 1976.
pPreliminary; — Nil; . . Not available.

Table 2. Canadian titanium production, trade and consumption, 1967-76

	Production		Imports			Consumption	
	Ilmenite[1]	Titanium Dioxide Slag[2]	Pure Titanium Dioxide	Extended Titanium Dioxide[3]	Total Titanium Dioxide Pigment	Titanium Dioxide Pigment	Ferro-titanium[4]
				(metric tons)			
1967	1 308 359	546 537	1 467	8 857	10 324	47 759	49
1968	1 469 117	610 447	2 165	8 797	10 962	50 684	20
1969	1 654 852	679 742	2 272	7 848	10 120	54 983	31
1970	1 892 305	766 310	2 523	7 415	9 938	44 391	25
1971	1 893 321	773 829	5 390	5 193	10 583	51 452	19
1972	2 048 879	834 996	5 346	1 081	6 427	52 738	133
1973	2 082 206	855 215	4 304	380	4 684	60 808	14
1974	2 017 483	844 750	4 060	251	4 311	58 551	14
1975	1 825 042	749 850	2 467	241	2 708	50 152	25
1976[p]	2 115 230	814 040	4 964	276	5 240	56 607	. .

Sources: Statistics Canada and company reports.
[1]Ore treated at Sorel from company reports. [2]Slag with a 70 to 72 per cent TiO_2 content, from company reports. [3]Approximately 35 per cent TiO_2. [4]Ti content.
[p]Preliminary; . . Not available.

World developments

The United States is one of the world's foremost producers and consumers of ilmenite. In 1976 ilmenite production in the United States is estimated at 561 550 tonnes and imports, including titanium slag from Canada, are estimated at 327 500 tonnes. The United States is also an important consumer of rutile. In 1976 natural rutile imports are estimated at 167 830 tonnes and synthetic rutile at 67 130 tonnes. Most of the rutile is used for pigment production through the chloride process, and about 10 per cent is used in the titanium metal industry. There was a limited demand for titanium metal in 1976, but an improvement is forecast for the near future. The marked decrease in demand resulted from a fall-off of activity in the commercial aviation industry, one of its principal consumers. The greatest potential for growth in demand for titanium metal will come from its increased use in chemical, industrial and commercial applications, because of its corrosion-resistant qualities. In the United States several projects are, or will be, commenced. Among the most important of these are the reopening of a plant of the Oregon Metallurgical Corporation (Oremet) at Albany in Oregon. Oremet hopes to recommence the production of titanium sponge and ingot by the beginning of 1977. The plant, which has been closed since 1971, has a production capacity of 1 360 to 1 800 tonnes a year of titanium sponge and ingot. Also, the Kerr-McGee Chemical Corporation has completed construction of its Mobile, Alabama plant. It will use the chloride process for TiO_2 pigment production. The plant will have a capacity of 45 360 tonnes of pigment a year. A second plant, also belonging to Kerr-McGee Chemical Corporation, and on the same site, should begin production of synthetic rutile early in 1977, at a rate of 100 000 tonnes a year. E. I. DuPont Nemours and Company is continuing construction of its plant with a 118 000-tonne annual capacity of TiO_2 pigments at Delisle, Mississippi. Finally, Butte Oil & Gas Ltd. is carrying out a feasibility study on a perovskite deposit in Colorado, reserves of which are estimated at 50 million tonnes of TiO_2.

Table 3. Titania slag and iron production, Quebec Iron and Titanium Corporation, 1971-76

	Ore Treated	Titania Slag	Iron
		(tonnes)	
1971	1 893 320	773 829	543 895
1972	2 048 879	834 996	581 997
1973	2 082 206	855 215	588 297
1974	2 017 483	844 750	562 083
1975	1 825 042	749 850	499 900
1976	2 115 230	814 040	551 078

Source: Quebec Iron and Titanium Corporation.

Australia is the most important world producer of rutile and ilmenite ore. In 1976 the production of rutile concentrate is estimated at 363 000 tonnes, and that of ilmenite concentrate at 771 000 tonnes. The following principal developments took place in Australia during the year. In March 1976 Allied Eneabba (Pty.) Ltd., commenced production of 200 000 tonnes a year of ilmenite, 50 000 tonnes a year of rutile and 100 000 tonnes a year of zircon. The concentrate plant of Western Titanium N.L. in the Eneabba region of West Australia commenced operations during the third quarter of 1976, and the first shipments should begin towards the end of the year. Westralian Sands Ltd., of West Australia plans to construct a plant with a capacity of 90 700 tons of synthetic rutile a year. Texasgulf Australia Inc. has discovered a major deposit of titanium-bearing magnetite in the Pilbara region of West Australia. The reserves in this deposit are several hundred million tonnes.

There are a number of other projects related to the titanium industry scattered throughout the world. One of the most important of these is at Richards Bay, in the Republic of South Africa. This project is jointly run by the Quebec Iron and Titanium Corporation (40 per cent), Union Corporation Limited (30 per cent), and the Industrial Development Corporation of South Africa (30 per cent). The last two of these partners are South African companies. The project is valued at $300 million and is expected to have an annual production of 56 000 tonnes of rutile, 115 000 tonnes of zircon, 399 000 tonnes of titanium slag, and 217 000 tonnes of pig iron with a low manganese content. Production should commence in 1980. The mine will be worked by Tisand (Pty.) Ltd. and the ore will be processed by Richards Bay Iron and Titanium (Pty.) Ltd., which will produce titanium slag with about 85 per cent TiO_2 content. Construction of a plant for production of synthetic rutile was completed at Ipoh in Malaysia by the Malaysian Titanium Corporation Sdn Bhd. The initial production figure was 55 000 tonnes a year. The Taiwan Alkali Corp. added a second unit to its plant at Kaoshsiung with a 13 600-tonne-a-year capacity for synthetic rutile. In England, Wogen Resources Ltd. com-

Table 4. Titanium statistics, United States, 1975-76

	Ilmenite (tonnes)		Rutile (tonnes)		Titanium[1] (tonnes)	
	1975	1976[e]	1975	1976[e]	1975	1976[e]
Production	637 000	562 000	. .	. .	. .	. .
Imports	304 000[2]	327 000[2]	203 000	235 000	3 801	1 452
Consumption	679 000[2]	882 000[2]	210 000	268 000	15 990	11 794
Price/kilo	. .	. .	. .	. .	$5.90	$5.90
Price/tonne	$54.10[3]	$54.10[3]	$782.60[4]	$562.20[4]	. .	. .

Source: U.S. Bureau of Mines, Commodity Data Summaries, January 1977.
[1]Metric tons of sponge metal. [2]Includes titania slag from Canada. [3]fob Atlantic Seaboard, 54 per cent TiO_2. [4]fob Atlantic and Great Lakes ports.
[e]Estimated; . . Not available, or not applicable.

Table 5. Consumption of titanium concentrates in the United States, by products, 1975

Product	Ilmenite[1] Gross Weight	Ilmenite[1] Estimated TiO_2 Content	Titania Slag Gross Weight	Titania Slag Estimated TiO_2 Content	Rutile Gross Weight	Rutile Estimated TiO_2 Content
	(tonnes)					
Pigment	668 785	384 920	134 232	94 878	173 953	164 317
Welding Rod Coating	. .	. .	—	. .	9 359	8 871
Alloys and Carbides	. .	. .	—	. .	. .	. .
Miscellaneous[2]	9 627	7 355	—	. .	26 636	25 413
Total	678 412	392 275	134 232	94 878	209 948	198 601

Source: U.S. Bureau of Mines, *Minerals Yearbook, 1975.*
[1]Includes mixed products containing rutile, leucoxene and ilmenite. [2]Includes ceramics, glass fibres and titanium metals.
— Nil; . . Not available.

pleted construction of its Sheffield factory, which by mid-1977 will produce 3 500 tonnes a year of ferrotitanium. In Brazil, New Jersey Zinc, along with two other Brazilian companies, Mineracao Vale do Paranaiba (VALEP) and Companhia Vale do Rio Doce, are working toward the development of a process which they hope can be used on the development of the deposits in the Tapira and Salitre regions in Minas Gerais for the production of titanium dioxide and upgraded ilmenite.

Table 6. Production of ilmenite concentrate by country, 1974-76

	1974	1975	1976[e]
		(000 tonnes)	
Canada[1]	845	750	816
Australia	831	1 030	1 002
Norway	848	527	767
United States	675	651	592
Finland	153	123	123
Malaysia	152	115	180
Sri Lanka	85	65	56
India	132	82	82
Spain	–	–	–
Brazil	7	5	5
Japan	–	–	–
Portugal	–	–	–
Total	3 728	3 344	3 623

Sources: U.S. Bureau of Mines, *Minerals Yearbook (1976), Commodity Data Summaries* (January 1977) and *Mineral Industry Survey.*
[1]Titania slag with 70 to 72 per cent of TiO_2.
[e]Estimated; – Nil.

In India, India's Metallurgical and Engineering Consultants Company have carried out a feasibility study for the construction of a plant having a 48 000 tonne-a-year capacity of titanium dioxide. The plant will be located in the State of Kerala and operated by the Kerala Minerals and Metals (KMM) Company. In Italy, the Societa Mineraria Italiana have announced the discovery of reserves in the order of 30 million tonnes of rutile ore and the possibility of producing 18 000 tonnes of concentrate a year. In Spain, Titanio, S.A., commenced production of TiO_2 pigment at Huelva. The new plant, with a capacity of 41 000 tonnes a year, uses the sulphate process developed by Tioxide International Ltd. N L Industries, Inc. completed plans for the construction of a plant with a 36 300-tonne-a-year capacity of pigment using the chlorine process. The plant will be constructed at Leverkusen in West Germany by Kronos Titan GmbH, a subsidiary of N L Industries, Inc. The Import-Export Bank agreed to an additional loan of $9 million to Sierra Rutile Ltd. to commence work on a deposit of rutile in Gbangbama in Sierra Leone, where production should commence in 1978.

Canadian minerals and deposits

Titanium is in ninth place in abundance among the elements which make up the earth's crust. Ilmenite ($FeTiO_3$) and rutile (TiO_2) are the two titanium minerals which have an economic potential at present. The theoretical composition of ilmenite is 52.66 per cent TiO_2 and 47.34 per cent iron oxide. It is found in igneous rocks, but deposits with an economic potential are limited to complex gabbro and anorthosite where the ilmenite is associated either with hematite or magnetite. Ilmenite deposits are also found in beach sand and placer deposits.

Table 7. Production of rutile concentrate by country, 1974-76

	1974	1975	1976[e]
		(tonnes)	
Australia	318 702	344 125	395 000
United States	5 847	. .	. .
India	3 400[e]	3 400	4 000
Sri Lanka	3 051	3 000	3 000
Brazil	146	140	. .
Total	331 146	350 665	402 000

Sources: U.S. Bureau of Mines, *Minerals Yearbook, 1976* and *Commodity Data Summaries,* January 1977.
[e]Estimated; . . Not available

Rutile is essentially pure titanium dioxide, but in nature it may contain up to 10 per cent impurities, chiefly iron and vanadium oxides. Rutile is found as an accessory mineral in several types of igneous, metamorphic and sedimentary rocks, but has economic value only when concentrated in beach or placer deposits, along with other heavy minerals such as ilmenite and zircon, and occasionally, cassiterite, columbite and tantalite.

Other titanium minerals such as brookite (TiO_2), anatase (TiO_2), perovskite ($CaTiO_3$), sphene ($CaTiSiO_5$) and leucoxene are frequently found in deposits of ilmenite and rutile, but rarely in sufficient concentration to have an economic value. Commercial grade ilmenite concentrates have a TiO_2 content between 44 and 60 per cent and rutile concentrates average about 95 per cent TiO_2.

The Canadian Shield, especially that part lying in the province of Quebec, contains a number of titanium-bearing deposits. Under existing technology and prevailing economics, only the high-grade ilmenite-hematite or ilmenite-magnetite deposits with a high titanium content attract much exploration activity, but the titanium-bearing magnetite deposits with a low titanium content have an important potential. These deposits have Fe content of about 20 per cent and a TiO_2 content of about 5 per cent. The reserves presently known amount to several billion tonnes.

Table 8. United States titanium metal data, 1972-76

	1972	1973	1974	1975	1976[e]
			(tonnes)		
Titanium sponge metal					
Imports for consumption	3 455	4 692	6 317	3 801	1 613
Industrial stocks	1 647	1 760	3 467	5 143	3 281
Government stocks	18 138	16 970	10 793	9 807	. .
Consumption	11 855	18 301	24 399	15 990	12 079
Scrap metal consumption	7 078	9 106	9 615	7 544	8 356
Ingot[1]					
Production	18 386	26 247	32 778	23 188	19 608
Consumption	17 689	23 051	28 633	22 213	19 055
Net production of mill products	11 455	13 182	15 824	14 177	. .

Source: U.S. Bureau of Mines, *Minerals Yearbook Preprint 1976.*
[1]Includes alloy constituents.
[e]Estimated; . . Not available.

The only deposit being worked in Canada at present is in the Lac Tio — Lac Allard region of eastern Quebec. This ilmenite deposit has a high titanium content and is mined by open-pit. It constitutes one of the world's largest deposits with reserves exceeding 100 million tonnes having a 35 per cent TiO_2 and 40 per cent Fe content.

Another ilmenite-hematite deposit with a high titanium content is situated near the St. Urbain region, 120 km northeast of Quebec. This high-grade deposit may be brought into production in the future if the present strength of the titanium market continues. The deposit has reserves estimated at 20 million tonnes with 38 per cent TiO_2 and 40 per cent Fe content.

A number of titanium-bearing magnetite deposits with a low titanium content are being explored at the present time. Among these are the Magpie deposit which is located 200 km northeast of Sept Iles and contains more than a billion tonnes of titanium-bearing magnetite with a 43 per cent iron, 10.5 per cent TiO_2, 1.6 per cent chromium and 0.17 per cent V_2O_5 content. Another deposit, belonging to the Natural Resources Ministry of Quebec, is situated in the Chibougamau region. The present estimated reserves of this deposit are in the order of 63 million tonnes with a 31 per cent Fe, 10 per cent TiO_2, and 0.5 per cent V_2O_5 content. A deposit owned by Titan Iron Mines and located in the North Bay — Temagami region, in eastern Ontario, has reserves in the order of 46 million tonnes with 39 per cent Fe, 19 per cent TiO_2, and 0.36 per cent V_2O_5 content. These deposits are potential sources of several elements of which titanium is only one. The Alberta Energy Resources Conservation Board is continuing studies of heavy minerals in the tar sands and estimates that the sands have a content of 0.21 per cent Ti and 0.05 per cent Zr. With a plant producing 19 875 cubic metres a day of synthetic crude oil, a by-product production of 284 000 tonnes a year of TiO_2 and 87 000 tonnes a year of ZrO_2SiO_2 could be expected from 103 x 10^6 tonnes a year of tar sands.

Processing and uses

The high opacity and extreme whiteness of titanium dioxide arise from its large index of refraction. Most titanium pigments (TiO_2) are obtained through the sulphate process, where finely crushed and concentrated ilmenite is digested by sulphuric acid. After solution is completed, the titanyl sulphate solution is clarified, filtered and boiled to precipitate the hydrated titanium oxide in the form of very small crystals. The resulting pulp is calcined in a rotary kiln before being classified and bagged. The chloride process is becoming more widely used, and consists, basically, of reacting the rutile with gaseous chlorine, to form titanium tetrachloride. The tetrachloride is then vapour-phase reacted at high temperature with oxygen and is transformed directly into TiO_2 pigment. The chlorine is recovered and recycled.

The pigment industry consumes about 90 per cent of all titanium mineral production. There are three different types of TiO_2 pigment on the market. Rutile and anatase are essentially pure titanium dioxide but have different indices of refraction and crystalline structures. The third type is a mixed titanium pigment which contains between 30 and 35 per cent of TiO_2, but is only produced in small quantities. Because of the high index of refraction, and resulting high opacity, more than half of the production of titanium pigment is used in the production of paints, varnishes and lacquers. Titanium metal has a silver-grey colour and low density, and is widely used because of its light weight, strength, and corrosion resistance. Titanium is an important material in aerospace applications because of its high strength-to-weight ratio, and is being more and more frequently used in the chemical and nuclear industry, as well as in desalinization plants and similar applications due to its corrosion resistance.

Outlook

Although a strong world demand for Sorelslag was foreseen in 1977, the demand for Sorelmetal, which is a coproduct of Sorelslag used mostly in the steel industry, will remain weak at least up to mid-1977. Because of this, the Quebec Iron and Titanium Corporation does not expect to increase its production by more than 5 per cent in 1977.

Table 9. Chemical composition of titanium concentrates

	Ilmenite	Rutile	Titania Slag
	(%)	(%)	(%)
TiO_2	37.0 -65.0	94.0 -98.0	71.4
Fe (FeO-Fe_2O_3)	30.0 -55.0	0.2 - 1.5	16.3
SiO_2	0.5 - 3.0	0.2 - 2.0	3.8
Al_2O_3	0.2 - 1.5	0.2 - 0.5	4.6
CaO	0.1 - 1.0	0.02- 0.08	0.8
MgO	0.05- 4.0	0.02- 0.09	5.0
Cr_2O_3	0.01- 0.5	0.1 - 0.3	0.19
V_2O_5	0.05- 0.5	0.4 - 0.8	0.58
ZrO_2	0.1 - 2.0	0.04- 0.4	—

Source: Roskill Information Services Ltd.
— Nil.

In Canada there was a heavy demand for titanium dioxide pigment during the year, but by the end of 1976 Canadian producers noted a hesitation on the part of consumers which has influenced the Canadian market during 1977. In spite of the price increase for primary materials themselves, along with the price increase for titanium dioxide pigments from American producers foreseen for July 1977, Canadian producers do not intend to increase their price during the coming year. The future growth of world demand for titanium dioxide pigment should amount to between 4 and 5 per cent per year.

A committee made up of Quebec Government representatives, along with representatives of Canadian titanium dioxide producers, is studying the pollution problem at the present time. Government authorities appear to be firm in their resolve that anti-pollution measures be taken by 1980. The procedure which will probably be used involves production of gypsum from the industrial wastes. The possible sale of this byproduct could offset the losses due to the treatment of the wastes.

An increase in the price of Sorelslag from $88.58 per tonne to about $100.88 is foreseen for the beginning of 1977.

Prices

Titanium prices in the United States published in Metals Week of December 27, 1976.

	($U.S.)
Titanium ore, fob cars, Atlantic and Great Lakes ports	
Rutile, 96%, per short ton, delivery within 12 months	510.00
Ilmenite, 54%, per long ton, shiploads	55.00
Slag, 70%, per long ton, fob shipping point	90.00
Titanium metal, sponge, per pound, fob mine or mill	
Max. 115 Brinell, 99.3%, 500 lbs.	2.70
Japanese, 99.3%	2.45 — 2.50
Mill products, per pound delivery, 4 000-lb. lots	
Billets, Ti-6AI-4V (8" diameter, random length)	4.86
Bars, Ti-6AI-4V (2" diameter)	7.48
Ferrotitanium, quoted in *Engineering and Mining Journal,* low carbon content, per pound of titanium delivered, 25 to 40% Ti	1.35
Titanium dioxide, Canadian pigment prices, quoted in *Canadian Chemical Processing,* effective November, 1976. Anatase, dry-milled, in bags, car lots, delivered East, per 100 lbs.	36.00

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General
32900-1	Titanium ore	exempt	exempt	exempt
34715-1	Sponge and sponge briquettes, ingots, blooms, rolled ingots, billets and milled titanium alloy stock for use in Canadian manufacture (expires 31 October 1977).	exempt	exempt	25%
34735-1	Titanium tubing or alloys for use in Canadian manufacture (expires 28 February 1977).	exempt	exempt	25%
34740-1	Titanium sheet or ribbon	15%	17.5%	25%
37506-1	Ferrotitanium	exempt	5%	5%
92825-1	Titanium oxide	exempt	12.5%	25%
93207-6	White pigment excluding pure titanium dioxide	exempt	12.5%	25%

United States

Item No.		
422.30	Titanium compounds	7.5%
473.70	Titanium dioxide	7.5%
601.51	Titanium ore, including ilmenite, ilmenite sands, rutile and rutile sands	exempt
607.60	Ferrotitanium and ferrosilicon titanium	5%
629.15	Titanium metal, non-wrought, scrap and rejects	18%
629.20	Titanium metal, wrought	18%

Sources: Revenue Canada, Customs and Excise, Canadian Customs Tariffs and Amendments, Ottawa. U.S. — Tariff Schedules of the United States Annotated (1976), TC Publication 749.

Tungsten

R. JOHNSON

Canada has only one producer of tungsten concentrates, Canada Tungsten Mining Corporation Limited. In 1976 Canada Tungsten produced 2 168 080 kilograms of tungstic oxide (WO_3) in scheelite concentrates, an increase of over 45 per cent from 1975. The higher production was the result of increased demand and a higher mill recovery of tungsten. One new discovery was reported during the year, that of Cordilleran Engineering Limited on the British Columbia — Yukon Territory border. In 1976 tungsten consumption in Canada is estimated to be down some 10 per cent from 1975.

Tungsten prices rose steadily throughout the year, principally as a result of abnormally heavy buying from the Eastern European countries. By year-end, tungsten concentrate prices had risen over 60 per cent from those prevailing at the beginning of the year. This large increase in price generated considerable interest in tungsten properties throughout the world. World production also increased in 1976, with improved operating results being recorded by several existing producers, and the opening of several new mines.

Tungsten will be in tight supply in the early part of 1977 and further price increases are expected; however, a slackening in the market is probable in the latter half of the year and consequently some easing of price is likely, probably to below beginning-of-the-year prices. As a result of new production capacity that came on-stream in 1976 and capacity which will come on-stream over the next several years, supply will likely outstrip demand, and an over-supply situation will probably emerge in 1978 that should last through to the end of the decade.

Canada, production and trade

There is only one producer of tungsten concentrates in Canada, Canada Tungsten Mining Corporation Limited. In 1976 Canada Tungsten produced 216 808 metric ton* units of tungstic trioxide (mtu WO_3) at its mine and mill in the Flat River Valley of the Northwest Territories, up from 147 775 mtu WO_3 in 1975. In addition, Canada Tungsten produced 4 617 kg of copper in concentrate. The large increase in production was the result of two factors: an improved market, which allowed Canada Tungsten to operate at 97.8 per cent of rated capacity as opposed to 92.7 per cent in 1975; and improved tungsten recovery in the mill; 81.6 per cent in 1976 compared to 71.1 per cent in 1975.

Canada Tungsten produces two types of concentrate at its mill — a gravimetric concentrate, which is ready for immediate sale, and a flotation concentrate, which requires removal of calcite before a marketable concentrate is produced. The flotation concentrate is shipped to Vancouver where the calcite is removed by washing with hydrochloric acid. The low recovery rate experienced in 1975 was caused by an unexpectedly high talc content in the ore. The talc principally affected the recovery rate for the flotation concentrate. Improvements to the mill circuits and the mining of a lower talc-containing portion of the orebody in 1976 were responsible for the improved recovery.

Canada Tungsten also announced that it will expand its mining and milling capacity by 1979. The expansion, which will cost some $10 million, will double Canada Tungsten's milling capacity from about 525 to 1 000 tonnes of ore a day by the summer of 1979. At the end of 1976, ore reserves on the property were estimated to be over 4 million tonnes averaging 1.55 per cent WO_3.

Brunswick Tin Mines Limited, a subsidiary of the Sullivan Mining Group Ltd., completed metallurgical testing on ores from its Mount Pleasant property, about 64 kilometres north of St. Andrews in Charlotte County, New Brunswick. The orebody has a complex mineralogy, and ore reserves have been estimated at 30 million tonnes in the Fire Tower Zone and 12 million tonnes in the North Zone, averaging 0.2 per cent tungsten, 0.08 per cent molybdenum, 0.08 per cent bismuth, about 5 per cent fluorite, 1.0 ounce-a-ton indium and minor amounts of copper, lead, zinc and tin. At the end of 1973 a decline was started to give access to the Fire Tower Zone for a bulk sample for

*A metric ton unit contains 10 kilograms, or 22.04 pounds.

Table 1. Canada, tungsten production, imports and consumption, 1975-76

	1975		1976^p	
	(kilograms)	($)	(kilograms)	($)
Production[1] (WO_3)	1 477 731	. .	. .	. .
Imports				
Tungsten in ores and concentrates				
United States	953	7 000	—	—
Total	953	7 000	—	—
Ferrotungsten[2]				
United Kingdom	38 102	429 000	75 296	865 000
United States	7 257	85 000	907	11 000
Others	—	—	907	15 000
Total	45 359	514 000	77 110	891 000
Metallic carbide tips or blanks				
United States		134 000		359 000
Sweden		90 000		30 000
Others		21 000		72 000
Metallic carbide inserts				
United States		1 087 000		2 170 000
Sweden		478 000		493 000
Others		688 000		825 000
Metallic Carbides nonagglomerated				
United States	382 514	3 229 000	234 235	3 568 000
Sweden	143 925	1 465 000	54 431	1 012 000
Others	6 622	58 000	2 087	41 000
Consumption (W content)				
Tungsten metal and metal powder	103 517	. .	. .	. .
Tungsten wire	13 362	. .	. .	. .
Other[3]	334 457	. .	. .	. .
Total	451 336	. .	. .	. .

Source: Statistics Canada.
[1]Producers' shipments. [2]Gross weight. [3]Includes tungsten ore, tungsten carbide.
^{p}Preliminary; . . Not available; — Nil.

metallurgical testing and to allow a better delineation of the deposit through underground drilling and sampling. A horizontal heading into the main orebody was completed early in 1975. Bulk samples were sent to the Department of Energy, Mines and Resources in Ottawa for testing. The tests investigated four possible flow sheets for the treatment of the ores. The samples contained a better-than-average tungsten content, about 0.3 to 0.4 per cent tungsten. Tungsten will be recovered as a concentrate, part of which, at least, will require leaching to remove associated minerals, and magnetic separation to produce a marketable product. The envisioned production is in the vicinity of 1 350 tonnes a day which would indicate a production level of about 1 000 tonnes of tungsten a year. Brunswick Tin is now in the process of trying to find a partner to participate in the development of the deposit.

AMAX Exploration, Inc., a wholly-owned subsidiary of AMAX Inc., reported in 1973 that it had identified a scheelite deposit in the MacMillan pass area, about 386 kilometres northeast of Whitehorse on the Yukon-Northwest Territories boundary. AMAX outlined, by exploration and drilling, a deposit with erratic mineralization and wide variation in grade. More than 30 million tonnes averaging 0.9 per cent WO_3 have been indicated. There has been no indication when development may commence.

One discovery was announced during the year. Cordilleran Engineering Limited announced that it had found an area of extensive tungsten mineralization on the British Columbia-Yukon Territory border. Grab samples taken from the area contained from 0.1 per cent WO_3 to, in one case, over 4.0 per cent WO_3. Cordilleran hopes to do further work in 1977 and to this end is currently seeking a partner willing to participate in an exploration program. AMAX Exploration has reportedly staked the area immediately to the north of Cordilleran's claims and will also undertake an exploration program in the summer of 1977.

Canadian consumption

In 1976 Canadian consumption of tungsten powders, ferrotungsten, tungsten chemicals, tungsten wire and tungsten scrap is estimated to have declined some 10 per cent from 1975. There is no conversion of tungsten concentrates to these intermediate products in Canada. The minimum economical plant size for ammonium paratungstate, the base material from which most of the intermediate products are derived, is about 1 300 000 kilograms a year. Even if all Canadian demand were supplied from a domestic plant, 60 per cent of the production would have to be exported; the primary market being the United States. Because of the high tariff structure prevailing in the United States, any Canadian producer is effectively barred from competing in that market. There is only one producer of intermediate products in Canada, Macro Division of Kennametal Inc. which produces tungsten powders from scrap. In recent years, a number of companies have at some time produced ferrotungsten; however, this has been on a sporadic basis and a ferrotungsten industry *per se* seems to be an unviable proposition in Canada.

The major consumers of intermediate tungsten products in Canada and the principal products consumed are:

A.C. Wickman Limited (c)
Kennametal of Canada, Limited (c)
Kennametal Tools Ltd. (c)
Sandvik Canadian Limited (c)
Valenite-Modco Limited (c)
Macro Division of Kennametal Inc. (m,s)
Atlas Steels Company Limited (f)
Deloro Stellite Division of Canadian Oxygen Limited (m)
Dominion Colour Corporation Limited (p)
GTE Sylvania Canada Limited (w)
Canadian General Electric Company Limited (c,w)
VR/Wesson Limited (c)
Firth Sterling (Canada) Limited (c)
Westinghouse Canada Limited (w)

c, carbide powders; m, metal powder; s, scrap;
f, ferrotungsten; w, wire; p, tungsten chemicals.

Tungsten in 1976

Estimated world production of tungsten contained in concentrate was some 41 200 tonnes in 1976, an increase of 7.8 per cent over 1975. In addition to mine production, 1 682 tonnes of tungsten in concentrate were released from the General Services Administration (GSA) strategic stockpile in the United States, compared with 1 875 tonnes in 1975. Because of the lower level of GSA releases, total supply of concentrates to the market increased by an estimated 7.0 per cent in 1976 over 1975.

Tungsten concentrate prices increased about 60 per cent during the course of the year. The main impetus for the price increase was heavy buying from Eastern European countries. The reason for the buying is unknown; however, it is generally believed to be related to a build-up in armaments by the Council for Mutual Economic Assistance (Comecon) countries, or possibly, the development of a strategic stockpile of tungsten in the U.S.S.R. Similarly, there were rumours that some western countries were also buying for defence purposes. This demand, coupled with a moderate increase in tungsten's industrial uses, created the tight market situation in 1976.

The People's Republic of China was also a bullish influence in the market. That country consistently quoted prices at the top end of, or above, the *London Metal Bulletin* price which is the standard reference price for tungsten sales world-wide, and, by so doing, maintained upward pressure on prices during the year. Another contributing factor to the price rise was probably the reluctance of both consumers and dealers to hold or acquire large inventories of high-priced tungsten, given its erratic price behaviour in the past.

Table 2. Canada, tungsten production, trade and consumption, 1965, 1970, 1974, 1975 and 1976

	Production[1]	Imports		Consumption
	WO_3 content	Tungsten ore[2]	Ferro-tungsten[3]	W content
	(kilograms)			
1965	1 734 837	162 114	160 572	398 079
1970	1 690 448	82 645	90 718	446 687
1974	1 613 700	—	185 973	534 958
1975	1 477 731	953	45 359	451 336
1976^p	. .	—	77 110	..

Source: Statistics Canada.
[1]Producer's shipments of scheelite (WO_3 content). [2]W content. [3]Gross weight.
^{p}Preliminary; — Nil; . . Not available.

International developments

Austria. Wolfram-Bergbau-Und Huttengesellschaft mbH started production from its mine at Mittersill in 1976. Wolfram-Bergbau, which is owned 47.5 per cent by Metallgesellschaft A.G., 47.5 per cent by Voest-Alpine AG, and 5 per cent by Teledyne Inc., will be Europe's first integrated tungsten producer, processing the ore through the ammonium paratungstate (APT) stage to tungsten-containing powders. In 1976, only the mine was in operation and some concentrates were sold. The processing operations will start in mid-1977. Mine capacity will be about 1 350 tonnes of tungsten in concentrate. Ore reserves are estimated to be in the area of 2.5 million tonnes averaging about 1.0 per cent WO_3.

Turkey. Etibank, the state-owned mining company, began tune-up operations at its new mine at Bursa. The mine initially was to have been in full production in 1975, but a fire destroyed part of the concentrator and necessitated the delay in the start-up operations. Mine capacity is about 3 000 tonnes of concentrate a year averaging about 65 per cent WO_3. Reserves are estimated to be some 13.5 million tonnes a year averaging about 0.7 per cent WO_3.

Brazil. One small producer, Brejui Mineracao e Metalurgica SA, started production during the year. Brejui, which is owned 51 per cent by Brazilian interests and 49 per cent by Japanese interests, will recover, from mine tailings, some 90 tonnes a year of tungsten concentrate containing 70 to 75 per cent WO_3.

Tungstenio do Brasil Minerios e Metais Limitada (TBMM) will start production of some 450 tonnes of WO_3 in concentrate a year in late 1977 or 1978 from a property in the state of Rio Grande do Norte. No reserve figures have been announced. Union Carbide Corporation has a 10.2 per cent interest in TBMM and will, through another subsidiary, market the concentrate world-wide.

Bolivia. Intubol, a new Bolivian tungsten firm, will build a $4.5 million tungsten complex at Viacha which, upon completion in 1978, will have the capacity to produce 2 000 tonnes a year of ammonium paratungstate and 1 000 tonnes a year of tungsten powders. A state-owned company, ENAP, holds 51 per cent of Intubol stock, with an option to increase its share to 66 per cent. The remaining stock is held by private interests in Bolivia.

United States. Union Carbide Corporation plans to open a new tungsten mine, the Tempiute mine, near Alamo Nevada in mid-1977. The mine initially was scheduled to begin production in 1976, but problems over obtaining a right-of-way for power lines to the property have delayed the start-up by one year. Although grade and reserves have not been announced, production will be some 1 500 to 2 000 tonnes of WO_3 in concentrate and the reserves are believed to be sufficient for 20 years of operation. The concentrate will be sent to Union Carbide's Pine Creek, California APT plant.

The recent increase in prices has led to renewed interest in some former tungsten producers in the United States. If prices remain firm, three former mines: the Strawberry mine in California; a former producer in Nevada, currently controlled by Oxbow Resources Ltd.; and the Tungsten Queen mine in North Carolina, may be reopened on a full-time basis. These mines, along with several other small producers, have intermittently produced tungsten over the last few decades.

In 1976, GSA stockpile releases were some 1 682 tonnes of tungsten contained in concentrate, down from 1 875 tonnes in 1975. On October 1, 1976, the Federal Preparedness Agency (FPA) increased the stockpile objectives for tungsten concentrate as follows:

	Stockpile Objective as of Oct. 1, 1976	Previous
	(tonnes W content)	
concentrate	4 002	1 905
ferrotungsten	8 060	—
metal powder	1 492	—
carbide powder	5 826	—

With the exception of concentrates, where current holdings exceed the objective by over 44 000 tonnes, all of the objectives for tungsten containing materials exceed present holdings.

Australia. Warman International Ltd. is Australia's largest producer of tungsten, operating a mine on King Island in Tasmania. The Bold Head and Dolphin orebodies have been developed to a stage where underground production could reach 350 000 tonnes of ore a year. Present mill capacity, however, is only around 300 000 tonnes a year, and Warman is planning to increase it to about 400 000 tonnes of ore a year. The mill expansion, when completed in 1978 or 1979, will increase production capacity by some 400 tonnes a year of tungsten in concentrate. In addition to the mill expansion, Warman will also construct a molybdenum cleaning circuit that will remove molybdenum from the tungsten concentrate. The presence of molybdenum in Warman's concentrate has restricted its usage in the past and the production of molybdenum-free concentrate should provide a greater sales potential in world markets.

There was also considerable interest in other tungsten properties during 1976. The best prospect for production appears to be the Mount Mulgine deposit of Minefields Exploration N.L. Minefields is currently seeking financing for the project. Presently envisioned plans call for a 100 000 tonnes-a-year ore concentrator.

United Kingdom. Because of the high tungsten prices, there was a good deal of attention focussed on former producers in the U.K. One former producer, the Carrock Fell mine, was brought back into production during the year. The initial production rate was 20 tonnes a day of ore averaging 0.9 per cent WO_3. This will be increased to 50 tonnes of ore a day in 1977.

Table 3. Tungsten production in ores and concentrates, 1974-76

	1974	1975	1976
	(tonnes contained tungsten)		
Europe			
France	593	867	756
Portugal	1 478	1 467[p]	1285
Spain	347	351	317
U.S.S.R.	7 600[e]	7 800[e]	8 000[e]
Austria	—	362	1 437
Total Europe*	10 280[e]	10 726[e]	12 068[e]
North America			
Canada	1 613	1 478	1 719
United States	3 554	2 495	2 662[e]
Mexico	309	277	270[e]
Total, North America*	5 482[e]	4 251[e]	4 652[e]
South America			
Bolivia	2 044	2 693	2 960
Brazil	911	1 133	1 100[e]
Peru	682	582	700[e]
Total, South America*	3 724	4 464	4 840[e]
Africa	659[e]	835[e]	850[e]
Asia			
People's Republic of China	8 500[e]	8 980[e]	9 000[e]
Democratic People's Republic of Korea	2 150[e]	2 150[e]	2 150[e]
Japan	769	811	832
Republic of Korea	2 180	2 533	2 423
Thailand	2 204	1 773	2 055
Total, Asia*	16 294[e]	16 729[e]	16 850[e]
Oceania			
of which Australia	1 125	1 533	1 919
Total, Oceania*	1 129	1 533[e]	1 925[e]
TOTAL*	37 500[e]	38 200[e]	41 185[e]

Sources: Tungsten Statistics July 1977, UNCTAD Committee on Tungsten; Statistics Canada and estimates by Mineral Development Sector.

*Totals may not be exact due to inclusions of other small producers.

[e] Estimated; [p] Preliminary.

Hermerdon Mining and Smelting Company is proceeding with the second phase of an exploration program on a tin-tungsten-china-clay prospect near Plymouth. The second phase will consist of a $500 000 drilling program and the construction of a pilot plant. Work to date indicates that there may be as much as 30 to 40 million tonnes of ore averaging 0.29 per cent WO_3 and 0.05 per cent tin. If this is indeed the case, it is conceivable that the United Kingdom could become self-sufficient in tungsten. Saint Piran Limited has commenced exploratory drilling at the former Castle and Dinas mine near St. Austell. The mine was last operated in 1956. Saint Piran is seeking extensions to the old lode, which contained ore grading 0.5 to 2.5 per cent WO_3.

Uses

From the viewpoint of consumption, the high price of tungsten ore, its relative shortage, variable supply and concern over world reserves have created a situation in which the general response of consumers has been to minimize tungsten usage where possible. Substitutions or partial substitutions have limited tungsten markets in the past and probably will restrict their growth, at least in the near-future. The principal uses of tungsten are in carbides, tungsten-bearing steels, nonferrous alloys, mill products and chemicals.

Tungsten carbide (WC) is one of the hardest materials known. It is produced by chemical combination of tungsten metal powder and finely divided carbon. Cobalt is added as a binder and the material is then compacted to the desired form and sintered to produce the cemented tungsten carbides. The largest end use of cemented tungsten carbides is in cutting tools, which includes both mechanically-held and brazed-in-place inserts. Cutting tools are used in machining steel, cast iron and nonferrous metals and for shaping in the woodworking and plastics industries. Tantalum, titanium and columbium carbides are frequently added to tungsten carbide-cobalt mixtures to lower the coefficient of friction of the cemented carbides and, thereby, produce grades better suited to the machining of specific products, particularly steel. In the more-abrasive applications such as dies for wire and tube drawing, punches and dies for metal forming, and bits and tools for drilling equipment and wear-resistant parts, a straight tungsten carbide-cobalt mixture is used almost exclusively. Other uses of tungsten carbide are in tire studs, studs in spikes for golf shoes, and armourpiercing projectiles.

Titanium carbide has been produced commercially in recent years, but on its own, it has not found wide applications. Titanium carbide compositions are extremely brittle, and under current technology it seems unlikely that titanium carbide will replace tungsten carbide to a major extent. However, the coating of tungsten carbide tools with 0.0002 inch of titanium carbide enhances their life in machining steel. This development may moderate the increased demand for tungsten carbide cutting tools. Ceramics may be substituted for tungsten carbides in applications involving machining with high speeds and light cuts, but ceramics usually lack sufficient toughness and wear-resistance, despite their greater hardness in the more-abrasive applications.

Tungsten carbides should retain the market for abrasive applications, i.e., wear-resistant and drilling applications. There will probably be a trend to the use of increasing amounts of mixed carbides for cutting tools, coating of tungsten carbide cutting tools to extend their life, and substitution of tungsten carbide in the less-abrasive applications by the cheaper ceramics and titanium carbide.

Tungsten is added to steels either as ferrotungsten (80 per cent W), melting base (30 to 35 per cent W), scheelite ($CaWO_4$) or as tungsten-bearing scrap. The principal tungsten-bearing steels are tool steels, used in some of the applications of the carbides, but usually in applications where lower operating temperatures are encountered. Some tungsten is also consumed in certain stainless steels that are used in elevated-temperature environments. In addition, tungsten was used in some magnet and die steels that have largely been supplanted by other products.

Tungsten usage in the steel industry has stagnated or declined in most countries because of the availability of low-cost substitutes. Molybdenum-tungsten tool steels have to a large extent supplanted tungsten tool steels. Molybdenum, while it imparts slightly inferior properties to the steel compared with tungsten, is a lower-cost addition and, because of this and its greater availability, molybdenum has been substituted for substantial portions of the tungsten in tool steels. There are competitive stainless steels for the tungsten-bearing stainless steels and the applications will largely determine which are used. At this time, it is probable that the maximum substitution for tungsten has occurred and that tungsten usage will again commence to grow in the steel industry. However, significant growth will occur only if the price and availability of tungsten are comparable with those of molybdenum.

The most important tungsten-containing alloys are superalloys, used in applications where high strength is required at high temperatures. The tungsten is usually added in the form of tungsten metal powder, although tungsten scrap can be used to satisfy part of the tungsten requirements. Superalloys can be classified into three principal types: nickel base, iron base and cobalt base. At present the principal usage of tungsten is in the cobalt-base or "Stellite" superalloys. The nickel- and iron-base superalloys currently contain little or no tungsten; however, several companies are developing new alloys that contain several percentages of tungsten and should substantially increase the use of tungsten in these superalloys. The expected rapid growth in usage of superalloys, combined with a greater use of tungsten in them, should make this an important growth market for tungsten.

The most important properties of tungsten in its metallic form are its high melting point, low vapour pressure, high hardness, good electrical conductivity and low coefficient of thermal expansion. Tungsten mill products are made by compressing the tungsten metal powder into the desired shape and then sintering the compressed shape to produce a uniform product. The principal tungsten products produced are rods, wire and flat products.

Discs cut from tungsten rods are used as electrical contacts. In this application tungsten furnishes improved resistance to heat deformation where sparking and high temperatures occur at electrical contact points. Pure tungsten contacts have found their principal use in ignition circuits of automobiles and aircraft but the trend to electronic ignition systems will decrease the use of tungsten in this application. Tungsten discs are also used as heat sinks in semiconductor applications. Tungsten is used in combination with other elements in electrical contacts and breakers for industrial applications.

Tungsten wire finds application for the filaments in incandescent lamps and for heating elements in fluorescent lamps and vacuum tubes. The use of vacuum tubes is declining, but tungsten usage overall should continue to grow as demand for different types of lamps grow. The use of tungsten wire in automobile windshields for deicing and defogging is a minor new application.

Flat products are used in fabricating parts of electron tubes and radiation shields and in parts for very high-temperature applications in reducing or inert atmospheres.

Among other uses of metallic tungsten, the most important is in heavy metals. Heavy metals are used in areas where counterweights or high-density material are required in limited spaces, e.g., in self-winding watches and in aircraft. Tungsten usage in heavy metals will grow at a slow rate because of the increasing availability and lower cost of depleted uranium, which has only a slightly lower density than tungsten. Steel tubes filled with tungsten carbide powder are used as electrodes in a welding method known as the Tungsten Inert Gas (TIG) method.

Tungsten compounds are used in small volume throughout the chemical industry. The principal end use is as sodium tungstate, phosphotungstate acid and phosphotungsmolybdic acid in dyes, toners, phosphors, chemical reagents and corrosion inhibitors. A minor and highly variable use is as petrochemical and chemical catalysts.

Price stabilization

From January 19 to 23, 1976, a meeting of the Working Group of the United Nations conference on Trade and Development (UNCTAD) Committee on Tungsten was convened to discuss alternative proposals for the stabilization of tungsten prices. The terms of reference for the Tenth Session of the Working Group on Tungsten included the following:

"Identify and evaluate the practical, economic and technical aspects of proposals which could be incorporated in an intergovernmental producer/consumer arrangement with special emphasis on the feasibility of proposals based on a system of minimum and maximum prices for the commodity; and proposals which would provide a system of exchange of necessary and timely data for the purpose of improving understanding of the market and greater stability of prices. In considering a system of minimum and maximum prices, the Working Group should give particular attention to and make recommendations, as appropriate, on:

(1) definition of the base product(s);
(2) appropriate price indicator;
(3) appropriate mechanisms to defend minimum and maximum prices;
(4) any other factors relevant to the successful operation of a system of maximum and minimum prices."

The terms of reference had been agreed upon at the Ninth Session of the UNCTAD Committee on Tungsten held at Geneva from July 28 to August 2, 1975, when a group of producer countries, led by Bolivia, advocated an international arrangement to stabilize tungsten prices.

The most constructive discussion took place on the first two items mentioned in the terms of reference-definition of the base product(s) and an appropriate price indicator. There was general agreement among producers and consumers on the range of products to be covered by an arrangement, the definition of these base products, the need to establish price differentials among these base products and the need to develop a more-representative price indicator. However, on the last two items mentioned in the terms of reference there was little agreement at all. While most producers wished to proceed almost immediately with the drafting of an arrangement to stabilize tungsten prices, some producers and several consumers, who expressed a willingness to consider price stabilization proposals, were not prepared to move at the speed which the proponent countries desired. Indeed, some consumers appeared to be opposed, or at best reluctant, even to consider price stabilization proposals. Given this wide divergence in attitudes, there was little opportunity to arrive at a consensus. At the Working Group meeting the recommendation was simply to instruct the UNCTAD Secretariat to prepare a document setting forth the major alternatives for a stabilization agreement for tungsten. This was, however, a compromise resolution and no general agreement was reached on the terms of reference. The recommendation was a stop-gap measure and essentially deferred any decision to the Tenth Session of the UNCTAD Committee on Tungsten, which met from November 15 to 19, 1976.

At the Tenth Session, producers and consumers were unable to resolve their differences. Most producers continued to press for the drafting of an international arrangement to stabilize tungsten prices, while most consumers held firm to their position that there was insufficient market transparency to proceed on the course and at the pace most producers wanted. As a result of this impasse, several producers decided to ask the Secretary-General of UNCTAD to bring to the attention of the Trade and Development Board, the senior administrative organization in UNCTAD, a proposal made by producers that a negotiating conference be called for the drafting of an international arrangement to stabilize tungsten prices. This proposed conference would implement the recommendations of an expert group, which would meet prior to the negotiating conference to discuss means of stabilizing tungsten prices. The Trade and Development Board is expected to respond to this presentation at its next meeting in April 1977.

Price

The *London Metal Bulletin* (LMB) price for tungsten concentrate rose steadily throughout the year from slightly over $U.S.85 a mtu WO_3 at the beginning of the year to over $140 a mtu WO_3 by year-end. The LMB price is the standard reference price for tungsten sales throughout the world. The LMB price is now quoted in U.S. dollars because of continued uncertainties concerning the pound sterling.

In 1976 *Metals Week* announced that it would begin publishing a tungsten quotation in 1977. The quotation will reflect only those transactions that take place in the United States market. Indeed, one of the principal reasons given for the new price quotation is that *Metals Week* feels the LMB price is dominated by prices paid in Europe and does not accurately reflect prices at which transactions are made in the United States market.

Outlook

The outlook for 1977 is uncertain because of the opacity surrounding present demand. Indications are that Eastern European buying will continue, at least through the first quarter of the year. Similarly, it is rumoured that buying for defence uses in the United States and Western Europe will also continue in 1977. However, there is a good possibility that the market should begin to ease in the latter half of the year, particularly when output from mines scheduled to come into production in 1977 reach the market. In the short term, the additional supplies from mines that came on-stream in 1976 and that will come on-stream during the next three years will probably lead to an oversupply. However, the longer-term outlook is unknown since it will depend largely on the action or inaction of the UNCTAD Committee on Tungsten and the Primary Tungsten Association. Actions by either group will undoubtedly affect price, and through it, consumption and production. Until such time as these situations become clarified, the future is uncertain.

Tungsten prices according to Metals Week for December 1975 and 1976.

	1975	1976
	U.S.	
Tungsten ore, 65% minimum WO_3 per stu of WO_3	effective Dec. 1, 1975	effective Nov. 29, 1976
G.S.A. Domestic, duty excluded	77.965	127.068
G.S.A. Export, duty excluded	77.169	127.000
L.M.B. ore quoted by *London Metal Bulletin,* cif	effective Dec. 11, 1975 77.023-80.691	effective Dec. 21, 1976 128.82-133.81
Ferrotungsten, per pound W, fob shipping point, low-molybdenum	effective Apr. 4, 1975 7.750	effective Nov. 1, 1976 9.250
Tungsten metal, per pound, cif U.S. ports		
Carbon red, 98.8%, 1,000 pound lots	. .	. .
Hydrogen red, depending on Fisher No. range	effective Aug. 8, 1975 10.210-12.010	effective Oct. 1, 1976 10.00-13.00

. . Not available.

Tariffs

Canada

Item No.		British preferential	Most favoured nation	General	General preferential
32900-1	Tungsten ores and concentrates	free	free	free	free
34700-1	Tungsten metal in lumps, powder, ingots, blocks or bars and scrap of tungsten alloy metal	free	free	free	free
34710-1	Tungsten rod and tungsten wire	free	free	25%	free
35120-1	Tungsten alloys in powder, pellets, scrap, ingots, sheets, strip, plates, bars, rods, tubing, wire (expires October 31, 1977)	free	free	25%	free
37506-1	Ferrotungsten	free	5%	5%	free
37520-1	Tungsten oxide in powder, lumps, briquettes	free	free	5%	free
82900-1	Tungsten carbide in metal tubes	free	free	free	free

Tariffs (concl'd)

United States

Item No.		
422.40	Tungsten carbide, on W. content	21¢ per lb + 12.5%
422.42	Other tungsten compounds, on W. content	21¢ per lb + 10%
601.54	Tungsten ore, on W content	25¢ per lb
607.65	Ferrotungsten, on W content	21¢ per lb + 6%
629.25	Tungsten metal waste and scrap, not over 50% tungsten, on W content	21¢ per lb + 6%
629.26	Tungsten metal waste and scrap, over 50% tungsten, on W content	10.5%
629.28	Tungsten metal, unwrought, other than alloys: lumps, grains, powders, on W content	21¢ per lb + 12.5%
629.29	Tungsten metal, unwrought, other than alloys; ingots and shot	10.5%
629.30	Other unwrought tungsten metal	12.5%
629.32	Unwrought tungsten alloys, not over 50% tungsten, on W content	21¢ per lb + 6%
629.33	Unwrought tungsten alloys, over 50% tungsten	12.5%
629.35	Wrought tungsten metal	12.5%

Sources: For Canada, the Customs and Tariff Amendments, Department of National Revenue, Customs and Excise Division, Ottawa. For United States, Tariff Schedules of the United States Annotated (1976) T.C. Publication 749.

Uranium

R.M. WILLIAMS

Events in 1976 carried mixed blessings for the Canadian uranium industry. One new mine was brought into production and established producers were well advanced with programs designed to increase their output. The tight supply situation remained which, with the considerably higher prevailing prices, gave impetus for companies to search for uranium. Northern Saskatchewan emerged as a prime target area of many companies, although exploration of one kind or another was going on in virtually every province as well as in the Yukon Territory and the Northwest Territories. The shortage of skilled miners continued to plague the industry despite substantial training and house-building programs established by most producers.

Late in December, the Government of Canada announced a further strengthening of the safeguard requirements which apply to the export of Canadian nuclear reactors and uranium. The government of Saskatchewan modified its initial uranium royalty proposal, made in November 1975, after hearing submissions from companies that assessed the effect of the original plan on their proposed operations. Late in the year, the government of Saskatchewan announced that a board of enquiry would be set up to investigate the implications of expanding uranium mining in the province, commencing with a review of the Cluff Lake uranium project.

Production of uranium in 1976 amounted to 4 850 tonnes* of uranium (U), substantially above the 3 512 tonnes U produced in 1975, due largely to an increased number of producers. Shipments of uranium however, including some inventory, amounted to 5 627 tonnes U. Of these total shipments, some 67 per cent came from three operations in Ontario, those of Denison Mines Limited and Rio Algom Limited, both in the Elliot Lake area, and Madawaska Mines Limited, which began production near Bancroft late in the year. The remaining production came from two operations in northern Saskatchewan, those of Eldorado Nuclear Limited near Uranium City and the joint Gulf Minerals Canada Limited-Uranerz Canada Limited project at Rabbit Lake, which began production in late 1975.

Production and development

Denison was well into its planned program to gradually increase its output and to eventually utilize its Can Met and Stanrock properties, which adjoin the east of its main property. By the end of 1975 the company had completed the expansion of its mill to handle up to 6 440 tonnes a day of ore, and on several occasions during 1976 it achieved this new capacity. A total of 1 380 740 tonnes of ore were treated during the year, with an average grade of 0.916 kg U/tonne (2.16 lb U_3O_8/ton)*, to produce 1 197 tonnes U. The mill was averaging over 5 440 tonnes of ore a day at year-end. Deliveries to Denison customers were drawn both from production and from inventory.

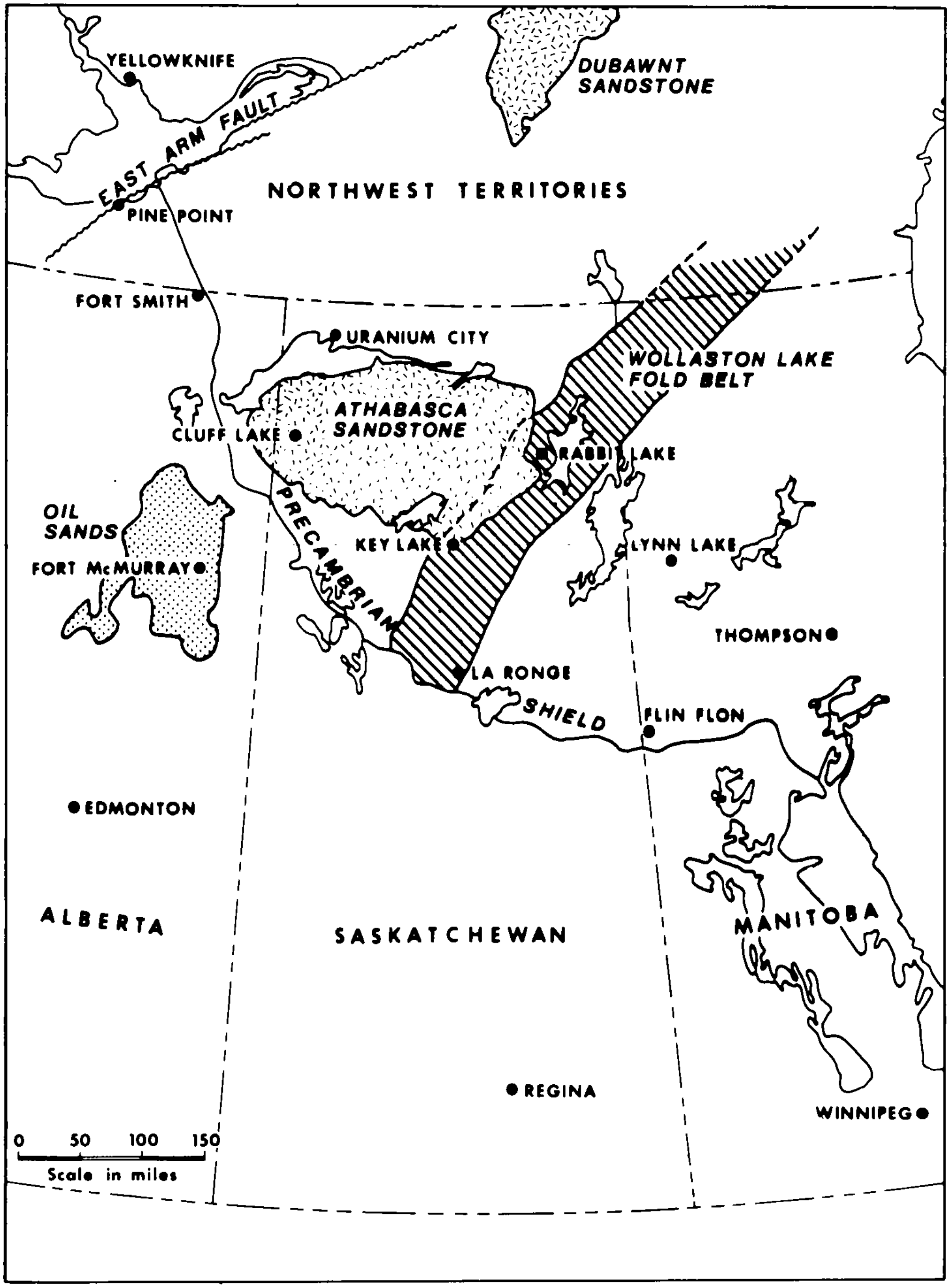
Efforts were concentrated during 1976 on projects which would boost ore production to some 9 070 tonnes a day, on the basis of a five-day week, to supply the newly expanded mill. A principal project was the installation of the north-south "C" axis conveyor belt system in the more easterly part of the main Denison orebody. The project was nearing completion at year-end, and was expected to be operational by mid-1977. A second major project which will contribute to increased production levels was the rehabilitation of the No. 1 shaft which has not been used as a production shaft for some time. Ore will initially be recovered from pillars in the proximity of the shaft and later a conveyorway will be reestablished to the western perimeter of the property for the recovery of pillars on a retreat basis.

Considering its main property together with those of Stanrock and Can Met, Denison has the capability to increase its mining and milling capacity still further. Some reports have suggested that the company's total current milling rate could be doubled; this would involve a further expansion of the main mine and mill,

*1 tonne (metric ton) uranium metal (U) = 1.2999 short tons uranium oxide (U_3O_8).

*Grades given in British units to facilitate comparison with 1975 production data; per cent U_3O_8 X 0.848 = per cent U.

Wollaston Lake Fold Belt and Related Areas, Saskatchewan



and the entities involved. Traditionally, mineral prospecting and exploration were virtually the exclusive prerogative of the mining fraternity. This is no longer the case with respect to uranium. Provincial and federal Crown corporations are participating in exploration ventures, as are foreign governments, either through their national agencies or through the provision of exploration funds to national companies. Electric power utilities, both foreign and domestic, are also financially backing uranium exploration programs in various ways.

The common motivation for most of these participants is the need for uranium to fuel their future nuclear electric generating plants. In this regard, the Federal Republic of Germany is financially assisting the West German firms of Urangesellschaft Canada Limited and Uranerz Exploration and Mining Limited, and the French government is participating through Compagnie générale des matières nucléaires (COGEMA)* in SERU Nuclear (Canada) Limited and Amok Ltd. Similarly, the Italian government, through its state-owned AGIP Exploration; the Japanese government through Power Reactor and Nuclear Fuel Development Corporation (PNC); the Spanish government, through Empresa Nacional del Uranio S.A. (ENUSA); and the British government, through the Central Electricity Generating Board (CEGB) are financially assisting uranium exploration programs in Canada.

Although an accurate measurement of the total extent of uranium exploration activity in Canada was not available in 1976, there appeared to be about 200 active companies which carried out some $40 to $50 million of exploratory work during the year. Uranium exploration was proceeding in all provinces and territories, with the possible exception of Prince Edward Island.

The area that was the most newsworthy in 1976 was northern Saskatchewan where, in the late 1960s, Gulf and Amok each made significant discoveries. These were followed by the Key Lake discovery, announced in late 1975, by Uranerz in partnership with Inexco Mining Company (Canada) Ltd. and the provincial Crown corporation, Saskatchewan Mining Development Corporation (SMDC). Named the Gaertner deposit, this discovery is located 160 km southwest of Rabbit Lake on the southern edge of the Athabasca sandstone. A second orebody, the Deilmann deposit, was discovered in mid-1976, about 1.5 km northeast of the first. Both of these deposits are characterized by high-grade nickel and uranium mineralization; the Gaertner deposit was reported to contain as much as 16 600 tonnes uranium and 16 000 tonnes nickel.

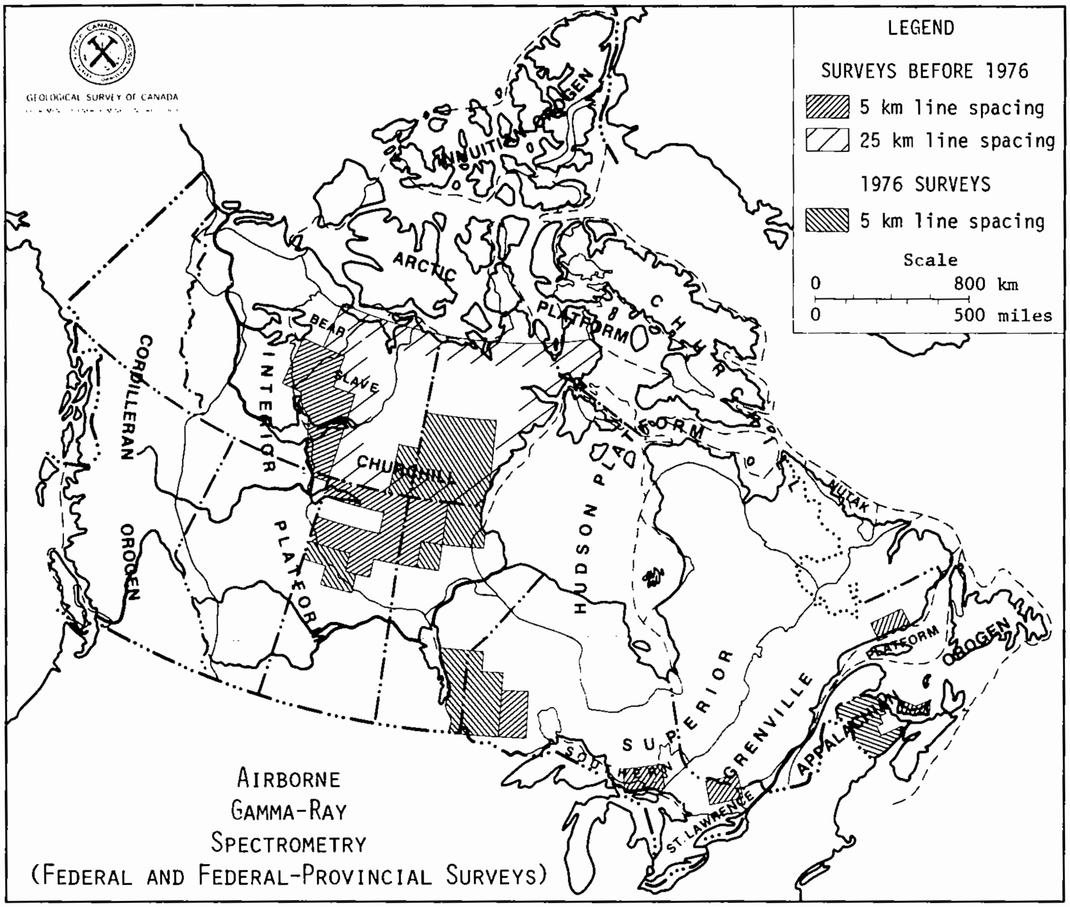
In addition to the Key Lake area, SMDC had an interest in more than 2 million square km in various holdings located around the periphery of the Athabasca sandstone basin. Some 50 companies held mineral rights around the perimeter of the basin which, at year-end, was the most active area in Canada for uranium exploration. Among the companies with which SMDC was associated in 1976 were: Denison and Urangesellschaft Canada Limited in the Charlebois Lake area; Power Reactor and Nuclear Fuel Development Corporation (PNC) north of Wollaston Lake; Conwest Exploration Company Limited and others in an area immediately east of Key Lake; Noranda Exploration Company, Limited in the Dudderidge Lake area; Eldorado and Amok in the Stoney Rapids area east of Lake Athabasca; and Eldorado in the Fond du Lac Area. Also of importance was a joint venture between Amok and Ontario Hydro on permits Amok holds on the northeast fringe of the Carswell dome.

The extent of SMDC's uranium exploration activity in Saskatchewan is significant, since it is largely through this company that the province will implement its legislative right to participate (up to 50 per cent) in all new mineral development programs in northern Saskatchewan. It is pertinent to note that Manitoba has promulgated similar legislation.

Uranium exploration activity seemed particularly prominent in the Bancroft area of Ontario. To the west of the Madawaska mine, over a distance of some 40 km, substantial mineral rights were either held directly by or were under option to Kerr Addison Mines Limited, Imperial Oil Limited, Inco Limited and Powerex Resources Limited. There are a number of deposits of uranium in the region, but their small size and somewhat erratic nature means that sufficient numbers of the deposits will have to be found to establish a viable base for production. Elsewhere in Ontario, Imperial drilled two deep holes on the Consolidated Morrison Explorations Limited property, which is due west of Rio Algom's Quirke mine, to give it a half interest in the ground; by year-end only marginal uranium values had been reported. Finally, Kerr Addison conducted surface work in the areas east and west of its Agnew Lake mine.

In Quebec, the Crown company Quebec Mining Exploration Company (SOQUEM) put increasing emphasis on uranium exploration. About half of its $2 million 1976 mineral exploration budget was spent on uranium projects, principal of which were the uranium-bearing carbonatite occurrence in the Lac Saint Jean area and joint ventures with Gulf and The Quebec Hydro-Electric Commission (Hydro-Québec) in the Otish mountain region. In the Johan Beetz area on the north shore of the St. Lawrence River, several companies were active, including Urangesellschaft, Denison and Imperial Oil, the latter two being in joint venture. Although uranium occurrences are fairly widespread, uranium grades reported have been comparatively low. In the James Bay region, Eldorado, SERU and the James Bay Development Corporation continued their extensive exploration assessment of

*A state company, established in January 1976, which has taken over all assets in the nuclear fuel cycle previously controlled by the Commissariat à l'Énergie Atomique (CEA).



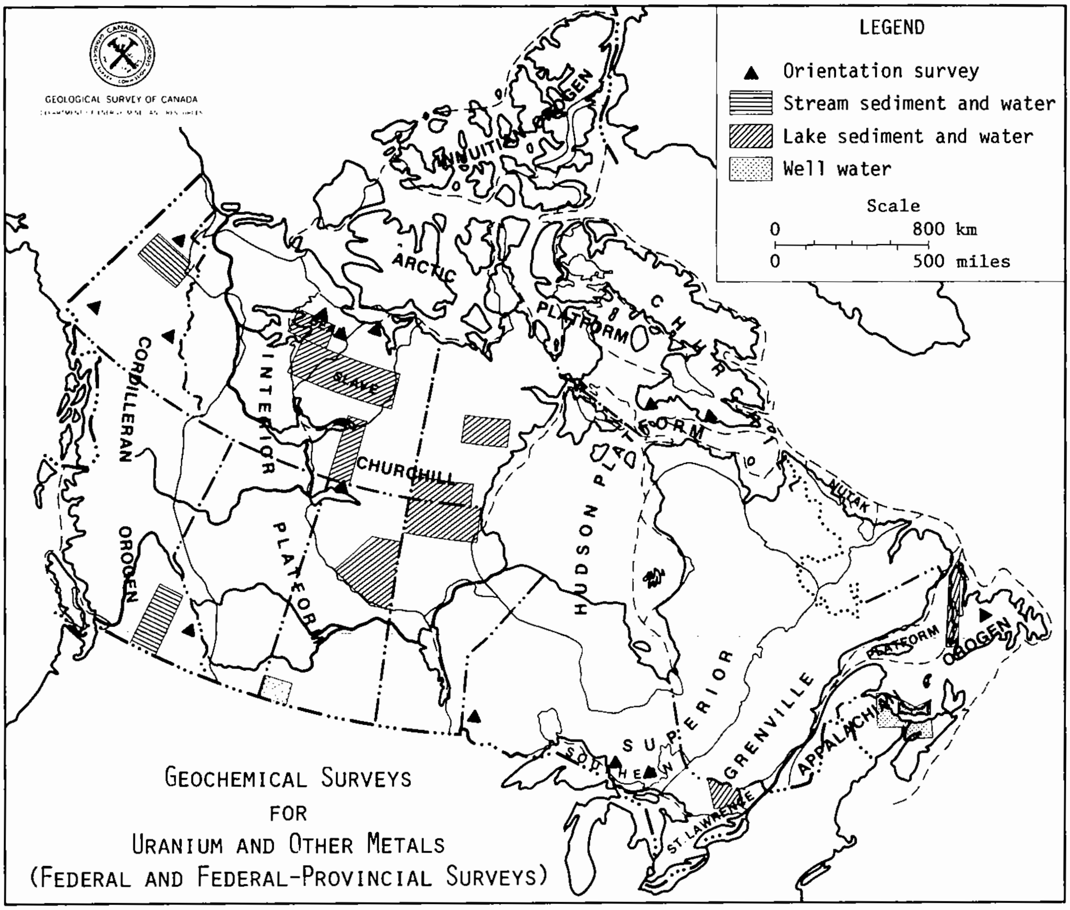
areas that will ultimately be flooded by the James Bay hydroelectric power development program. In the Mont Laurier region, Urangesellschaft and Imperial each were active, as was Denison in joint venture with Canadian Johns-Manville Company, Limited.

The Beaverdell area, near Kelowna, British Columbia, has emerged as a potential uranium-producing region. A number of companies had obtained mineral rights, prompted by the success of Power Reactor and Nuclear Fuel Development Corp. (PNC) which had been active in the area since the late 1960s. This company made its first discovery in 1968 in the Tertiary sandstone and conglomerate sediments at the base of the Plateau formation. Of the companies active in the area, only PNC and Tyee Lake Resources Ltd. carried out substantial drilling programs. Although PNC did not report in detail on its discoveries, Tyee Lake reported the discovery of a uranium deposit with an extent of some 135 by 135 metres and about 12 metres thick at depths of from 45 to 60 metres, having a uranium content of something over 0.03 per cent U a tonne.

Uranium reconnaissance program*

The Federal-Provincial Uranium Reconnaissance Program was continued in 1976, and the results of several of its 1975 field projects were released during the year. The main objective of the program is to provide high-quality data to indicate areas of Canada where there is the greatest probability of finding new uranium deposits. The first aim of the program is to ensure that all regions of Canada where the earth's crust contains an above-normal amount of uranium are known and adequately delineated. The program is primarily concerned with airborne gamma-ray spectrometry and regional geochemistry. The plan envisages a balanced

*See the *Canadian Uranium Reconnaissance Program,* a paper by A.G. Darnley, presented to the American Nuclear Society, Washington, November 1976.



program of geophysics and geochemistry, with surveys taking place each year in several provinces and in the territories. The general principle of coverage is that surveys will move outwards from areas of known uranium mineralization.

During 1976 the program covered approximately 555 000 square km, including 450 000 by airborne gamma spectrometry and 220 000 by regional geochemistry; these surveys included 115 000 square km covered by both methods. In 1976, maps covering areas in nine provinces and the Northwest Territories were released, as highlighted in the accompanying sketch maps. Finally, in August 1976, the Department of Energy, Mines and Resources announced that shared-cost agreements had been entered into with New Brunswick, Ontario, Saskatchewan and British Columbia for various airborne gamma-ray spectrometry and regional geochemical surveys under the Uranium Reconnaissance Program. The value of these new agreements totals $3 584 000, of which one-half will be provided by the federal government.

Canadian uranium resources

The second annual report of the Department of Energy, Mines and Resources' Uranium Resource Appraisal group (URAG) was released in June 1976. As in the first report released in August 1975, URAG presented resource estimates in three classifications, recoverable at up to the world price and twice the world price. The world price in mid-1975 was judged to be $20 a pound U_3O_8, thus estimates were for resources recoverable up to $40 a pound U_3O_8* as shown in Table 3.

*Although quantities are expressed in tonnes (metric tons) of uranium metal, prices are quoted in dollars per pound of uranium oxide (U_3O_8) since the pound U_3O_8 continues to be the commodity of international commerce. ($1/lb U_3O_8 = $2.6/kg U).

Table 3. 1975 estimates of Canada's recoverable uranium resources

Mineable	Measured		Indicated		Inferred	
			(tonnes uranium)[1]			
Up to $20/lb U_3O_8	63 100	(59 200)[2]	82 300	(82 300)	173 900	(182 300)
$20 to $40/lb U_3O_8	10 800	(3 100)	16 900	(13 100)	85 400	(64 600)
	73 900	(62 300)	99 200	(95 400)	259 300	(246 900)

[1]To convert to short tons U_3O_8 multiply by 1.299 and round to nearest 1 000 tons. [2]Figures in brackets are from the 1974 assessment using price categories of up to $15/lb U_3O_8, and $15 to $30/lb U_3O_8.

After deducting 1975 production of 3 512 tonnes U, the resources had increased by 7.8 per cent over those reported for 1974. Part of the increase was due to a more extensive study of data on deposits in established mines, and part to the discovery of new resources. Little impact was produced by increasing the assessment price, because of inflation experienced in Canada in 1975. Based on these total resource estimates, URAG projected that annual Canadian uranium production would increase to 5 850 tonnes U in 1976; 10 000 tonnes U in 1980; and 11 540 tonnes U in 1984. As noted earlier, 1976 production fell significantly short of this projection.

The Group also made an assessment of uranium resources not covered in the tabulation of *measured, indicated* and *inferred* resources. These additional resources are contained in extensions to known uranium deposits, or in concealed satellite deposits in known uranium districts; the resources had not had sufficient development work done on them to place them in the more reliable categories. The estimated quantities in this *prognosticated* category amounted to 129 200 tonnes U recoverable up to $20 a pound of U_3O_8 and a further 216 900 tonnes U recoverable at prices between $20 and $40 a pound U_3O_8.

Governmental initiative

On December 22, 1976 the Honourable Donald C. Jamieson, Secretary of State for External Affairs, announced that the federal government had decided upon a further strengthening of safeguard requirements which apply to the export of Canadian nuclear reactors and uranium. The new policy states that shipments to *non-nuclear weapon states* under future contracts will be restricted to those countries which ratify the Non-Proliferation Treaty or otherwise accept international safeguards on their entire nuclear program. Nuclear export policy, as announced in December 1974, required binding assurances that whatever Canada provides will not be used to produce a nuclear explosives device, but did not cover whatever a country receives from other suppliers or what it might do on its own. The new policy is intended to close this gap, giving Canada assurance by treaty that its nuclear customers will have been selected from those countries which have made a clear and unequivocal commitment to the non-proliferation of nuclear weapons.

Legislation covering the federal government's foreign owernship policy respecting new uranium mines, initially announced in 1970, was expected to be presented to Parliament during the then-current session of Parliament. The ownership legislation, to be entitled *The Uranium and Thorium Mining Review Act,* will retain the 33-per-cent limitation on nonresident ownership at the mining and milling stage. However, the 10-per-cent limitation for each individual foreign shareholder, enunciated in 1970, will be dropped. Although nonresident ownership may be limited to 33 per cent, access to uranium supplies by the nonresident partner could be higher, limited only by conditions imposed under the uranium export policy, announced in September 1974. Flexibility will be provided in the Act to meet special circumstances, such as the impact of minor share ownership fluctuations. Once promulgated, the legislation will be administered by the Foreign Investment Review Agency (FIRA) which also administers the Foreign Investment Review Act, the second part of which will also affect new foreign uranium exploration activity in Canada.

Following a successful period of government-industry discussion, the Saskatchewan government instituted a new two-part uranium royalty system, effective August 1, 1976. First, there will be a basic royalty of 3 per cent of the gross value of sales. Second, there will be a graduated royalty, with the marginal rate of tax being determined on the basis of the rate of return on capital invested in the project. Generally in the calculation of the capital investment figure, computed interest during the exploration and pre-production period will also be included. In the calculation of operating profits for graduated royalty purposes, deductions will include production costs, operating social costs, and the basic royalty, as well as designated allowances for such items as marketing costs, working capital and head office expenditures. All social investment costs may be written off at stipulated rates in determining the graduated royalty. The rates of the graduated royalty are as follows:

When the Ratio of Operating Profit To Capital Investment Is:	Graduated Royalty Is:
Below 15 per cent	0
On that portion above 15 per cent but below 25 per cent	15 per cent of operating profit in this bracket
On that portion above 25 per cent but below 45 per cent	Amount in previous bracket plus 30 per cent of operating profit in this bracket
On that portion above 45 per cent	Amount in previous brackets plus 50 per cent of operating profit in this bracket

No graduated royalty will be payable until the producer or producers have accumulated operating profits equal to their investment base. In other words, the graduated royalty does not come into effect until after payout has been achieved. In conjunction with these provisions, a tax credit equal to 35 per cent of new exploration expenditures will be provided for those new companies carrying out work in Saskatchewan. This credit will be allowed against graduated royalties.

Late in 1976 the government of Saskatchewan announced that it would set up a board of enquiry to investigate the implications of the proposed Cluff Lake uranium mining project. The Board was to look at the specific environmental, occupational health, and safety aspects of the proposed project, as well as review the overall implications of expanding uranium mining in Saskatchewan. This latter aspect of the inquiry was to deal with the broader questions of nuclear development from a provincial, national and international point of view.

The report of the Royal Commission on the *Health and Safety of Workers in Mines* by Professor James Ham of the University of Toronto was submitted to the government of Ontario in June 1976. The report recommend the formation of an Occupational Health and Safety Authority, under the Ontario Ministry of Labour, that would amalgamate responsibility for health and safety which was then currently shared among provincial and federal departments and agencies. The major portion of the report was concerned with occupational diseases related to uranium mining. In addition to recommending the establishment of regulations which would set threshold limit values for respirable silica dust, and maximum permissible annual exposure to ionizing radiation for uranium miners, other standards were suggested, designed to improve mine ventilation practices and the monitoring of the health of miners. The report, which included 117 recommendations, was met with approval by government, labour and industry and will, undoubtedly, lead to positive action by all concerned.

Markets and prices

The sellers' market for uranium, which had become firmly established in 1975, continued to provide impetus to uranium exploration on a worldwide basis. Prices appeared to stabilize in the area of $40 a pound U_3O_8 early in the year. The Nuclear Exchange Corporation (NUEXCO) which publishes a uranium "value", based on current bids to buy, was quoting $41.50 a pound U_3O_8 at year-end for immediate delivery. NUEXCO's projected uranium values, including escalation, were quoted at $43.40, $46.90, $50.65 and $54.70 a pound U_3O_8, for delivery at mid-year, in the years 1977 through 1980, respectively.

In contrast to these "values", the United States Energy Research and Development Administration (ERDA) reported that the average price for 1976 uranium deliveries in the United States was $10.70 a pound U_3O_8; the majority of these deliveries were under "fixed-price" type contracts. ERDA also reported that future estimated average delivery prices under contract as of July 1, 1976, range from $12.60 a pound U_3O_8 for 1977 delivery to $19.90 a pound U_3O_8 for delivery in 1985. United States' producers entered into new sales contracts totalling 19 600 tonnes U during the first six months of 1976, bringing total commitments for the period 1976 to 1985 to 110 700 tonnes U.

The marketing strategy of uranium producers changed during the preceding two to three years from one which committed uranium at a base-price, indexed to reflect increases in costs of labour and materials, to one which employs the world market price concept. Under the latter system, contracts are based on the world market price at a time of delivery or an escalating floor price, whichever is higher. Still other pricing approaches were being developed involving novel arbitration arrangements and various forms of advance payments toward shares in production. Consumer strategy had also undergone considerable change, as more and more utilities were participating directly in exploration and production ventures in an effort to assure their long-term requirements.

Although a number of small Canadian uranium sales were mentioned in the press during 1976, only one new contract, between Agnew Lake Mines Limited and Korea Electric Company for the delivery of 230 tonnes U, was announced and approved by the Atomic Energy Control Board (AECB); proceeds of the sale were reported at $23.8 million. At year-end Agnew Lake also consummated agreements with a group of four United States utilities* for the sale of 423

*Yankee Atomic Electric Company, Vermont Yankee Nuclear Power Corporation, Maine Yankee Atomic Power Company and the Public Service Company of New Hampshire.

Table 4. Exports of uranium concentrates from Canada, 1965, 1970-1976

	United States[1]	Britain	West Germany	Japan	Others	Total
			(thousands of dollars)			
1965	17 140	39 573	426	179	1 941	59 250
1970	20 148	9 482	103	266	3 982	33 981
1971	18 491	11 517	170	173	3 048	33 399
1972	49 824	17 546	352	254	2 224	70 200
1973	48 686	17 407	278	445	891	67 707
1974	65 226	22 795	198	292	11 362	99 873
1975	97 725	19 046	304	1 773	10 540	129 388
1976	198 277	24 328	288	1 068	19 768	243 729

Source: Statistics Canada, exports of radioactive ores and concentrates and radioactive elements and isotopes which cleared customs.
[1] For the years 1970 to 1976 almost entirely destined for a third country following enrichment, primarily West Germany and Japan.

tonnes U for delivery between 1977 and 1980, and these agreements were submitted to the AECB for approval. Negotiations were also under way at year-end between Agnew Lake and the Swedish Nuclear Fuel Supply Company and a contract was expected to be signed early in 1977. As of June 1976, total contractual export commitments by Canadian producers were about 84 600 tonnes U.

Pertinent to Agnew Lake's sales efforts was a loan agreement signed with Eldorado in September 1976, whereby Agnew Lake borrowed 423 tonnes U and would have the option to borrow a further 539 tonnes by December 31, 1977. The company must pay interest on the outstanding value of uranium borrowed and must re-deliver concentrates of like quantity within four years of the date of borrowing.

Refining and enrichment

Output of uranium hexafluoride (UF_6)* at Eldorado's Port Hope, Ontario refinery increased by 35 per cent in 1976 to 3 325 tonnes U as UF_6. The program to expand the UF_6 circuit to 4 540 tonnes U a year continued, with completion expected in late 1977. As one of five commercial uranium refiners in the world, Eldorado converts uranium concentrates to UF_6 for a variety of customers in Europe, Japan and the United States. Several major contracts for UF_6 conversion were executed during the year, primarily with Japanese customers, and a number of additional agreements were expected to be concluded early in 1977.

Output of Eldorado's other principal product, natural ceramic-grade uranium dioxide (UO_2), remained about the same in 1976 at some 505 tonnes U as UO_2. Natural UO_2 powder is subsequently pelletized at Canada's two fuel-fabricating facilities (Westinghouse Canada Limited at Port Hope and Canadian General Electric Company Limited at Peterborough, Ontario) for fabrication into fuel elements for Canada's nuclear power program, as well as for first cores for CANDU exports. In anticipation of the increased UO_2 requirements of Canadian utilities forecasted for the mid-1980s, plans were made in 1976 to construct a new processing circuit of significantly higher capacity.

Both the UO_2 and the UF_6 circuits are fed by a solvent extraction circuit which converts mine concentrates to nuclear-pure uranium trioxide (UO_3). Expansion of the UO_3 plant, which had begun in 1974, continued throughout 1976, with the objective of increasing its nominal capacity from 4 540 tonnes U a year to more than 5 440 tonnes U a year by 1978.

During 1976 Eldorado completed preliminary examinations of 17 potential Ontario sites for a new 9 070-tonne-U-a-year UF_6 plant. On January 7, 1977 the company announced that a site at Port Granby, 14.5 km west of Port Hope, was its preferred choice; the site includes the company's current residue management area. A detailed environmental impact assessment of the project was in preparation at year-end and upon completion in 1977 would be the subject of public hearings under a federal environmental assessment review panel. The company was also conducting feasibility studies on the possibility of locating an additional refinery in Saskatchewan in the 1980s.

Two study projects have been undertaken in Canada to examine the possibility of establishing a domestic uranium enrichment facility. In 1970 Brinco Limited began studying the possibility of establishing a plant based on United States gaseous diffusion technology, although this did not lead to a firm proposal. Numerous other alternatives were examined by the company, using gas centrifuge technology, until the program was phased out in late 1975. In early 1974, a second study was undertaken jointly by James Bay Development

*Uranium hexafluoride is the required feed material for the uranium enrichment process.

Corporation, SERU Nuclear (Canada) Limited (subsidiary of the French Commissariat à l'Énergie Atomique (CEA)*), Canadian Pacific Investments Limited and Cominco Ltd., to examine the possibility of utilizing power from Quebec's James Bay hydroelectric power project to operate a plant based on French gaseous diffusion technology; a joint company, CANADIF, was formed to carry out the study. In late 1975, however, Canadian Pacific and Cominco withdrew from the project following completion of the first phase of the study, largely because the required investment had a much longer payback time than their normal business investments.

Due to the CANADIF project and various other developments in the energy and uranium enrichment fields, the government of Canada undertook a review, beginning in late 1975, to determine if it should revise its policy on uranium enrichment, enunciated in August 1973. This review was completed in mid-1976 and a report was awaited at year-end.

Nuclear power developments

As of late 1976, some 78 000 electrical megawatts (MWe) of nuclear power capacity was operating throughout the world (excluding China, USSR and Eastern Europe). In addition, some 177 000 MWe were under construction and another 147 000 MWe were committed by orders or letters-of-intent for a total commitment of over 400 000 MWe**. Within Canada, 9 CANDU reactors with an aggregate capacity of 4 028 MWe were operating by year-end and a further 16 reactors with an aggregate capacity 11 305 MWe were either under construction, committed, or planned (see Table 5).

The highlight of 1976 was the start-up of the first two units of Ontario Hydro's Bruce "A" Generating Station. Unit 2 started up on July 27, 1976 and was synchronized to the grid by September 4th; by year-end it was operating at 63 per cent of reactor power. Unit 1 was started up for the first time on December 17, 1976 and by February 1977 the Atomic Energy Control Board had authorized the operation of both units at 88 per cent of reactor power, thus allowing them to produce their full electrical output; a portion of the Bruce "A" steam output will be provided to Ontario Hydro's heavy-water production plants. Meanwhile, construction of Units 3 and 4 proceeded satisfactorily.

Perhaps the other most noteworthy accomplishment in nuclear power in Canada in 1976 was the continued remarkable performance of Ontario Hydro's Pickering "A" Generating Station. Some 19 per cent of Ontario's electricity can now be attributed to nuclear power, most of which is generated at Pickering. The 4-unit station operated during 1976 with an average capacity factor of over 93 per cent, with total unit energy costs of 7.8 mills per kilowatt-hour, approximately half the cost of operating the coal-fired Lambton Generating Station, if it were run on base-load operations.

The Douglas Point Generating Station, which provides some 65 per cent of its output to the Bruce Heavy Water Production Plant, operated at a capacity factor of 90 per cent until a planned shut-down in September. The NPD Generating Station completed its 15th year of operation, and achieved a new record of an average 92 per cent capacity factor for the year; the power plant operations. Although Atomic Energy of Canada Limited's (AECL's) Gentilly 1 station (a CANDU-Boiling Light Water prototype)* was restarted in December, following extensive modifications to its shutdown and turbine control systems, it was shut down soon after to permit a realignment of its turbine.

Construction of Pickering "B" (a duplicate of Pickering "A"), Gentilly 2 and Point Lepreau generating stations continued more or less on schedule. The project schedule for Bruce "B" (a duplicate of Bruce "A" with certain changes) was approved during the year and engineering work continued toward that end. Formal commitment for the Darlington Generation Station, to be located near Bowmanville, Ontario, was still pending at year-end. Ontario Hydro also continued with studies of various options for subsequent plants, one of which would utilize a 1 250-MWe CANDU reactor.

Outlook

In the wake of the oil crisis of 1973-74, the adequacy of energy supply has become of paramount concern to virtually every nation in the world. The significant increases in energy prices which the world has begun to experience have succeeded in emphasizing the fact that there is indeed a limit to our non-renewable mineral fuel resources. In response to these realities, efforts have been evident in many areas to curb the increase in growth of total energy demand through conservation and other means.

These efforts, abetted by environmentalists and shortages in capital financing, were reflected by late 1976 in downward adjustments in energy requirement forecasts, particularly in the United States and western Europe. World nuclear power capacity was expected to reach some 620 000 to 675 000 electrical megawatts (MWe) by 1990 and 1.4 to 1.6 million MWe by the year 2000, compared with a low forecast of 875 000 and 2.0 million MWe, respectively, published by the Nuclear

*In January 1976, all assets in the nuclear fuel cycle controlled by the CEA were transferred to the State company, Compagnie générale des matières nucléaires (COGEMA)

**Merlin, H.B. *Uranium's Role in Shaping the Future,* paper presented to Annual Meeting, CIM Newfoundland Branch, St. John's, November 5, 1976.

*Gentilly 2 will use a conventional CANDU-Pressurized Heavy Water reactor.

Table 5. Nuclear power plants in Canada, 1976

Reactors	Owner	Net Output (MWe)	In-Service Dates
(a) **Operating**			
Nuclear Power Demonstration	Atomic Energy of Canada Ltd.	22	1962
Douglas Point	Atomic Energy of Canada Ltd.	208	1967
Gentilly 1	Atomic Energy of Canada Ltd.	250	1971
Pickering 1 to 4	Ontario Hydro	2 056	1971-73
Bruce 1 and 2	Ontario Hydro	1 492	1976
Subtotal		4 028	—
(b) **Under construction or committed**			
Bruce 3 and 4	Ontario Hydro	1 492	1978-79
Pickering 5 to 8	Ontario Hydro	2 064	1981-83
Gentilly 2	Quebec Hydro-Electric Commission	638	1979
Point Lepreau	New Brunswick Electric Power Commission	635	1981
Bruce 5 to 8	Ontario Hydro	3 076	1983-86
Subtotal		7 905	—
(c) **Planned**			
Darlington 1 to 4	Ontario Hydro	3 400	1985-88
Subtotal		3 400	—
Grand Total		15 333	—

Sources: 1975 assessment of Canada's Uranium Supply and Demand, Department of Energy, Mines and Resources, Canada, June 1976; Merlin, H.B., *op. cit.*

Energy Agency (NEA) one year earlier. World uranium requirements were expected to grow from the level of some 19 000 tonnes U a year in 1976 to between 90 000 and 115 000 tonnes U by 1990, and to between 140 000 and 175 000 tonnes U by the year 2000.

In common with other countries, Canadian projections of installed nuclear capacity and associated uranium requirements were also modified downward. Installed nuclear capacity in the year 2000 was expected to be in the order of some 75 000 MWe, compared with some 115 000 MWe projected just over a year earlier. Domestic uranium requirements would grow, under this scenario, from 450 tonnes U a year in 1976 to 4 200 tonnes U in 1990, and to 11 000 tonnes U a year in the year 2000.

Despite the downward adjustments in the forecast for nuclear power development, the world's uranium-producing industry was still expected to accomplish a seven- to nine-fold expansion in output over a 25-year period. In light of the various problems associated with exploration and development, this continued to be viewed as a formidable task compared to similar expansions required for other mineral commodities. Canada's uranium industry had begun to expand however, and it seemed able and ready to expand still further in response to these increases in demand. Hopefully, a favourable economic and governmental climate will facilitate these activities so that Canada can do its part in contributing to the solution of the world's energy needs.

Vanadium

R. JOHNSON

There is no vanadium pentoxide (V_2O_5) produced in Canada either from domestic ores, or vanadium-containing residues, or from imported raw materials. One company, Masterloy Products Limited, produces ferrovanadium from imported vanadium pentoxide. Canada is not a major user of vanadium, consuming less than 500 tonnes a year of ferrovanadium.

In 1976 vanadium consumption in the noncommunist world declined for the second year in succession. This, coupled with an increase in production capacity, resulted in a slow market. There was one price increase during the year; however, because of the softness of the market, some material was reportedly being sold at prices lower than the published prices.

In 1977 consumption is expected to increase some 5 per cent, but as the result of further additions to production capacity, the market is expected to remain soft. There will likely be an overcapacity situation in vanadium to the end of the decade because of large increases in productive capacity coming on-stream in the Republic of South Africa, Finland and the United States.

Minerals and occurrences

Vanadium is found in most parts of the world, but it rarely occurs as the sole mineral of economic interest. Identified world reserves and resources[1] (Table 2) total some 56.25 million tonnes* of contained vanadium of which some 17 per cent, or 9.7 million tonnes, are classified as being economically mineable reserves. Approximately two-thirds of these resources are contained in the magnetites and titaniferous magnetites of the Republic of South Africa, the U.S.S.R., the United States, Finland, India, Chile, Australia and Canada. The vanadium contained in tar sands and in crude oil represents about 14 per cent of world resources, and that in phosphate rock or phosphatic shales about 12 per cent.

The principal economic minerals of vanadium are:

carnotite	$K_2O \cdot 2U_2O_3 \cdot V_2O_5 \cdot 3H_2O$
roscoelite	$2K_2O \cdot 2Al_2O_3(Mg,Fe)O \cdot 3V_2O_5 \cdot 10SiO_2 \cdot 4H_2O$
descloizite	$4(Cu,Pb,Zn)O \cdot V_2O_5 \cdot H_2O$
titaniferous magnetite	$FeO \cdot TiO_2$-$FeO \cdot (Fe,V)O_3$ and V_2O_5 in solid solution
phosphate rock	$Ca_5(PO_4)_3(F,Cl,OH)$ with VO_4 replacing some PO_4 ions

At present, the principal sources of vanadium are the titaniferous magnetites of the U.S.S.R., the Republic of South Africa, Finland, Norway, and a magnetite deposit in Chile. The other major sources are: Namibia, where the vanadium occurs as descloizite in a lead-zinc mine; and several sources in the United States, including the uranium mining operations of the southwest United States where vanadium occurs as carnotite and roscoelite; the phosphate rock mined in Wyoming, and a possibly unique deposit in Arkansas where vanadium is the primary constituent of several minerals. In recent years vanadium has also been recovered from the fly ash or boiler residues of petroleum, and as a byproduct of the leaching of bauxite in alumina plants.

Marketable products

Vanadium is sold in three basic forms: as an oxide concentrate, as technical-grade vanadium pentoxide, and as fused vanadium pentoxide. Vanadium mine production, an oxide concentrate, is sold in a variety of forms, depending on the type of deposit from which it is being mined and the degree of processing undertaken in the producing country.

Once an oxide concentrate has been produced, the

[1] Vanadium chapter, *Mineral Facts and Problems,* 1976. United States Department of the Interior.

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

processing stream for all V_2O_5 concentrates is similar. The concentrate is crushed and ground and mixed with a sodium salt, usually sodium chloride or sodium carbonate. This mixture is then roasted and the vanadium is recovered as sodium metavanadate, a water-soluble salt. Following leaching with water and a pH adjustment, the vanadium is recovered as sodium hexavanadate, also known as red cake. The sodium hexavanadate is fused at 700°C and a dense black product known as technical grade vanadium pentoxide, which contains about 85 per cent V_2O_5, is produced. A further processed form, fused vanadium pentoxide, can be produced by dissolving the technical-grade vanadium pentoxide in an aqueous solution of sodium carbonate. Other metallic impurities are then precipitated out of the solution by adjusting the pH level. The vanadium is recovered as ammonium metavanadate which is then calcined and roasted to produce fused vanadium pentoxide, which contains 99.8 plus per cent V_2O_5. While this process is usually applied to vanadium concentrates only, it is also the basic form of concentration for some of the uranium-vanadium ores in the United States. In these cases, the uranium is recovered by washing the red cake (sodium hexavanadate) with acid and refiltering. This leaves a 'pure' precipitate of red cake and a solution from which the uranium can be recovered.

The form of the oxide concentrate varies considerably from mine to mine. In some cases, such as the lead-zinc ores of Namibia, a suitable concentrate is recoverable directly while in others, such as the titaniferous magnetites of the Republic of South Africa, the vanadium must be converted to an oxide. In Namibia, the vanadium concentrate is recovered from the mill tailings following the extraction of the lead and zinc minerals. For the recovery of vanadium from the titaniferous magnetites of the Republic of South Africa, the process is more involved. Highveld Steel and Vanadium Corporation Limited has developed its own process whereby the ore, containing the equivalent of about 1.75 per cent V_2O_5, is first partially reduced in a kiln. The hot discharge is then fed into an electric furnace where the vanadium and iron are separated from the titanium. The Vanadium and iron are recovered jointly in a high-vanadium pig iron, while the titanium goes into the slag. To produce a vanadium concentrate, the pig iron is then blown with oxygen and the vanadium is oxidized and carried off in a second slag. The slag contains about 25 per cent V_2O_5 and constitutes Highveld's oxide concentrate. The "cleaned" pig iron is used in steelmaking. Similarly, the U.S.S.R. produces a high-vanadium slag, containing 17 to 21 per cent V_2O_5, from its titaniferous magnetites. In the United States a vanadium-bearing slag is also produced from the treatment of phosphate rock. The phosphate rock is melted with sand and coke in an electric furnace. The phosphate rock is reduced to phosphorous and the vanadium, which is present as vanadium pentoxide, goes out in the slag. This slag contains about 6 per cent vanadium.

Technical-grade V_2O_5 and fused V_2O_5 are used as reference products insofar as price is concerned because they are relatively homogenous products. The prices for oxide concentrate are usually negotiated directly between producers and consumers because of the variations in form and grade.

Canada

Vanadium occurrences are widespread throughout Canada. The most frequent type of occurrence is vanadium contained in titaniferous magnetites. While the grade of these deposits, at up to 0.6 per cent V_2O_5, is comparable to the grade of some deposits now being worked in other countries, it is only about one-third of the grade of the titaniferous magnetites being mined for vanadium in the Republic of South Africa. There is also some vanadium associated with uranium ores in Canada, but the grade is too low to warrant economic recovery. There are few known occurrences in Canada where vanadium is the principal metal of interest. Most commonly, these occur as vanadium minerals dispersed in a layer of sandstone, limestone or shale; however, the grade, at less than 0.3 per cent V_2O_5, is less than one-third the grade of a primary vanadium deposit now being worked in the United States.

The best prospect for economic recovery of vanadium in Canada at present is the vanadium associated with the bitumen of the Alberta tar sands. While the bitumen itself contains only 0.02 to 0.05 per cent V_2O_5, the fly ash, or residue remaining after the petroleum is extracted from the bitumen, contains 2 to 4 per cent V_2O_5. Tests on alternate means of recovering the vanadium from the fly ash have been done by the Canada Centre for Mineral and Energy Technology (CANMET) of the Department of Energy, Mines and Resources. The results of these tests and summaries of three possible flowsheets for the recovery of vanadium have been published in Mines Branch Investigation Report 1R72-23, *Pyrometallurgical Recovery of Nickel and Vanadium from Athabasca Tar Sands Fly Ash.* Several companies have expressed interest in pursuing these investigations.

No vanadium pentoxide is currently produced in Canada. Two companies; Masterloy Products Limited and Petrofina Canada Ltd., have, however, produced V_2O_5 in the past. Masterloy produced vanadium from sodium fluorovanadate, which was recovered as a residue from the bauxite leaching circuits of the Aluminum Company of Canada, Limited at Arvida, Quebec, and from fly ash, which was recovered as a flue dust from oil-fired power plants. The sodium fluorovanadate and fly ash were fused with soda ash prior to digestion in sulphuric acid and filtration. Precipitation with an ammonium salt left a filter cake of ammonium metavanadate, which was then converted to vanadium pentoxide. Masterloy then used the vanadium pentoxide to produce ferrovanadium. In 1973, when Alcan found it uneconomic to continue the recovery of sodium fluorovanadate, Masterloy tried to use fly ash alone but this proved unsuccessful because of inconsistencies in the feed material and, as a result, stopped production. The company does, however, still produce ferrovanadium. Petrofina recovered V_2O_5 from the residues of Venezuelan crude oil but stopped production in 1971 when its refinery feed was changed to a lower vanadium-bearing crude from the Middle East.

Table 1. Canada, vanadium imports and consumption, 1975-76

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Imports				
Ferrovanadium				
United States	100	1 023 000	105	884 000
Consumption				
Ferrovanadium				
Gross weight	435	..	..	..
Vanadium content	341	..	..	..

Source: Statistics Canada
[p] Preliminary; .. Not available

Canadian consumption of ferrovanadium as reported by Statistics Canada was 435 tonnes in 1975. The principal consumers are: The Steel Company of Canada, Limited; The Algoma Steel Corporation Limited; Atlas Steels Division of Rio Algom Limited and Sydney Steel Corporation. Ferrovanadium is also used in small quantities by several other steel producers in Canada. Although no statistics are collected on the consumption of vanadium chemicals in Canada, vanadium salts are known to be used in the chemical industry as catalysts and in the production of paints.

Vanadium in 1976

Noncommunist consumption of vanadium is estimated to have declined some 4.3 per cent to 27 900 tonnes of V_2O_5 in 1976. While demand for line pipe remained firm during the year, the continued slackness in the steel market, particularly for constructional steels, and a lower level of activity in the aircraft industry, were responsible for the decline. Noncommunist world supply is estimated to have declined some 2.2 per cent during the year to 30 900 tonnes of V_2O_5. Reduced production from the Republic of South Africa was responsible for the decrease.

International developments

Republic of South Africa. The Republic of South Africa is the world's largest producer of vanadium. Expansions currently under way by the three South African producers — Highveld Steel and Vanadium Corporation Limited, Ucar Minerals (Pty.) Limited and Transvaal Alloys (Pty.) Limited — will not only maintain its position as the world's largest producer but increase its share of world production.

Highveld is the world's largest single producer of vanadium. In 1976 the company completed construction of its sixth electric furnace at Witbank. The furnace is scheduled to be fully operational by mid-1977. This will increase Highveld's annual production capacity to about 15 000 tonnes of V_2O_5 contained in slag. By 1980, capacity is expected to approach 20 000 tonnes of V_2O_5 a year. In addition to its main operation at Witbank, Highveld also produces vanadium at its Vantra Division. The Vantra Division was formerly an independent producer, Transvaal Vanadium (Pty.) Limited.

Ucar, a subsidiary of Union Carbide Corporation, is in the process of doubling the capacity of its vanadium mine and mill at Britts. The expansion, when completed in mid-1977, will increase Ucar's capacity to some 5 500 tonnes of V_2O_5 in slag a year.

Transvaal Alloys, a joint venture of two Federal Republic of Germany (West Germany) firms; Otavi Minen und Eisbahn Gesellschaft and Vereinigte Aluminium-Werke, started an expansion program in 1976. When completed in 1978, capacity will be some 1 800 tonnes a year of V_2O_5 in slag.

Table 2. Identified world vanadium resources

Country	Reserves	Resources	Total
	(000 000 tonnes contained vanadium)		
Republic of South Africa	1.8	16.3	18.1
U.S.S.R.	7.3	3.6	10.9
Canada	—	10.0	10.0
United States	0.1	9.0	9.1
Others	0.5	7.6	8.1
Total	9.7	46.5	56.2

Source: United States Bureau of Mines.

Finland. Rautaruuki Oy, a state-owned enterprise involved in the production and processing of ferrous metals, is Finland's only producer of vanadium. In 1976 Finnish production of V_2O_5 was some 2 600 tonnes in slag. Up until 1976 the vanadium pentoxide was produced solely as a byproduct of iron at the Otanmaki mine. During the year a new vanadium mine, the Mustavaara mine of Rautaruuki, started production. This mine has an annual capacity of 3 000 tonnes of V_2O_5 in concentrate.

Norway. The only producer of vanadium in Norway is A/S Rodsand Grüber, a subsidiary of Elkem-Spegerverket A/S. The mine, which currently has an annual capacity of 90 000 tonnes of pig iron and 750 tonnes of V_2O_5 a year, is considered too small to be competitive. Consequently, the company has applied for permission to expand its operation. Present plans call for a tripling its capacity to 250 000 tonnes a year of pig iron and 2 000 tonnes a year of V_2O_5. It is expected that the expansion will be completed by 1980.

United States. The United States is the world's second-largest producer of vanadium. At present there are three producers: Union Carbide Corporation, from a primary vanadium deposit in Arkansas and as a co-product of uranium at a mine in Colorado; Kerr-McGee Corporation, which recovers V_2O_5 from the slag of phosphorus producers; and Atlas Corporation, a new producer that began production in 1976 from a vanadium recovery unit added to its uranium mine and mill at Moab, Colorado. The new Atlas plant has the capacity to produce some 1 350 tonnes a year of V_2O_5.

Table 3. Estimated noncommunist world supply and consumption of V_2O_5, 1974-76

	1974	1975	1976
	(000 tonnes V_2O_5)		
Production[1]	30.6	31.6	30.9
Republic of South Africa	17.1	18.7	17.4
United States[2]	7.9	7.7	7.8
Finland	2.6	2.3	2.6
Other Market Economies	1.5	1.7	1.7
U.S.S.R.[3]	1.5	1.2	1.4
Consumption	31.3	29.1	27.9

[1]United States only on a recoverable basis; others on a contained vanadium basis. [2]Recoverable basis. [3]Exports to market economy countries only.

Cotter Corporation, a subsidiary of Commonwealth Edison Company Limited, announced plans to add a vanadium recovery unit to its Schwartzwalder uranium property in Colorado. The unit when completed in 1979 will have the capacity to produce about 1 000 tonnes of V_2O_5 a year.

The General Services Administration (GSA) stockpile objective was increased during the year. The Federal Preparedness Agency (FPA) recommended that the stockpile objectives for vanadium be set at about 2 350 tonnes for vanadium pentoxide and about 9 150 tonnes for ferrovanadium. There were no stockpile objectives prior to the FPA recommendation. Current holdings are some 500 tonnes of V_2O_5.

U.S.S.R. The U.S.S.R. produces V_2O_5 in slag as a byproduct of the smelting of titaniferous magnetites from the Kachkanar open pit in the Urals and from Lisakovsk in Kazakhstan. The slag averages 17 to 22 per cent V_2O_5. The U.S.S.R. is planning to increase production from the Kachkanar area and also to install vanadium recovery units at some alumina plants in order to produce vanadium pentoxide from bauxite residues.

Chile. Compania de Acero del Pacifico, Chile's only vanadium producer, is expanding its iron- and steel-making complex at Huachipato. The expansion will also result in increased vanadium production. Once the plant is fully operational production should rise to about 1 500 tonnes of V_2O_5 in slag a year.

Philippines. It has been reported that there are plans to construct a pig iron plant to treat the Lingayen iron sand. The plant, when operational in 1978, would also produce a vanadium-bearing slag.

Uses

The steel industry is the largest single outlet for vanadium. In steel-making, vanadium is utilized primarily for its ability to refine grain size in steel. Grain refining increases the yield strength of most carbon steels and is the principal means for increasing the toughness of a steel. Vanadium's ability to form stable carbides and nitrides within the iron matrix of a steel imparts further increases in yield strength and improves weldability, wear resistance and high-temperature strength; it can, however, also lead to a decrease in toughness.

Vanadium is used in making steels that require high strength and toughness or are subject to severe wear conditions. The vanadium content of most steels is low, usually less than 0.2 per cent. It is usually added to steels as ferrovanadium, which can contain anywhere from 30 to 80 per cent vanadium. The term, ferrovanadium, includes both iron-vanadium alloys and a recently developed group of carbon-vanadium alloys.

The most important and fastest-growing outlet for vanadium within the steel industry is the high-strength, low-alloy (HSLA) steels. HSLA steels were developed in response to the demand for structural steels of a higher yield strength than that provided by ordinary carbon or carbon-manganese steels. Vanadium and other elements such as niobium found rapid acceptance in this area as it was found that by the addition of relatively small amounts of these elements, the desired properties could be obtained without necessitating any major changes in production practices. The major uses of HSLA steels are in pipelines, concrete reinforcing bars and the construction of general structures such as high rise buildings and bridges.

Vanadium has found its widest use in those HSLA steels used in the manufacture of pipe for the transmission of petroleum and natural gas. One method of moving increased volumes of these commodities in recent years was to build pipelines that could withstand a higher line pressure. However, the yield strength of ordinary carbon steels was insufficient to tolerate increases in line pressure so a vanadium containing HSLA steels has been widely employed by several countries in recent years. Large quantities of vanadium-bearing HSLA steels have been manufactured and used in the United States, West Germany and the United Kingdom for petroleum and natural gas pipelines and gas mains. Vanadium has also been used in pipeline steels designed to operate in specific environments, such as the Arctic. For example, the Aleyeska pipeline in Alaska is made of vanadium-bearing steel pipe.

In recent years yield-strength requirements for concrete reinforcing bar have risen by about 50 per cent and further increases are anticipated. While these higher yield strengths can be achieved by increasing the amounts of two of the traditional steelmaking elements, carbon and manganese, the resulting loss in weldability makes this action undesirable. Vanadium has been used to increase the yield strength and maintain weldability and this application is expected to provide a further growth area. HSLA steels are finding, and will continue to find, increasing applications in structures such as bridges and elevated roadways, and in transportation equipment such as rail cars and automobiles. In the latter use, HSLA steels can provide a saving in weight because of the higher yield strengths. However, a number of additives are competing with vanadium in HSLA steel manufacturing. While the market share that vanadium will capture due to increase in demand cannot be quantified with accuracy, this use will represent a growth area for vanadium.

The earliest use of vanadium in steel was as an addition to tool steels used for high speed machining. Vanadium inhibits grain growth and enables the steels to maintain their hardness, and therefore their cutting edge, at the high temperatures generated in the tool tip from high speed machining. This remains an important application for the metal. Vanadium is used both in the high-tungsten tool steels that were first developed and in the later generations of molybdenum-tungsten tool steels.

Vanadium is also used in making high-temperature steels such as those employed in steam power plants for steam pipes and headers. Other areas of use in the iron and steel industry include: heavy iron and steel castings, forged parts, such as crankshafts; automobile parts, such as gears and axles; springs, ball-bearings, and hammers and dies.

The most important use of vanadium in nonferrous alloys is in the aircraft industry. A vanadium-aluminum alloy is added to titanium to increase the high temperature strength of titanium, a property that is essential in jet engines, high speed air frames and rocket engine parts. Also, the addition of the vanadium-aluminum alloy effects a weight saving, a factor that is becoming increasingly important in aircraft design. Some vanadium is also used in iron-base superalloys employed in jet engines and turbine blades where high-temperature strength is essential. Some vanadium is added to copper-base alloys to control gas content and refine the microstructure. A small amount is added to the aluminum alloys of internal combustion engine pistons to improve high-temperature operating properties. A potential use for vanadium alloys is as a cladding material in fast-breeder nuclear reactors. Vanadium has a low neutron capture cross-section (i.e. permits relatively free movement of neutrons within the reactor core), good resistance to corrosion by liquid sodium (the reactor coolant), and good high-temperature operating properties.

Vanadium is used in making vanadium carbide, employed in the manufacture of both hand and machine tools; and in the production of various chemical salts. Compounds of vanadium are used in the chemical industry as catalysts in the production of sulphuric acids and the cracking of petroleum products. Other uses in the chemical industry include: the colouring of glass and ceramics, driers in paints and varnishes, processing of colour films, in welding rods and in wear-resistant materials.

Prices

One increase of between 10 and 15 per cent in the price of vanadium products occurred in mid-1976. Reports indicate that sales were made below the posted prices in the latter half of the year because of the relatively slow market. The price stability apparent in 1976 came after a two-year period of rapid price increases during which prices rose some 70 to 80 per cent.

Outlook

In 1977 vanadium consumption is expected to increase as a result of increased demand for vanadium-containing constructional steels and a higher level of activity in the aircraft industry. Demand for line pipe is also expected to remain firm. Overall, an increase in consumption of about 5 per cent can be expected. However, the market is expected to remain soft because of new capacity that came on-stream in 1976, and that will come on-stream in 1977.

In the medium-term, large increases in production capacity in the Republic of South Africa, the United States and Finland may well give rise to an overcapacity situation. In the longer-term, the demand for vanadium is expected to exhibit strong growth as HSLA steels receive a wider usage. The potential for increased supplies from the Republic of South Africa, and the possible entry of new producers such as Canada and Australia, should provide adequate supplies.

Prices

United States vanadium prices published in Metals Week.

	December 29 1975	December 31 1976
	($U.S.)	
Vanadium pentoxide, per lb of V_2O_5, fob mine or mill		
Air dried (technical)	2.98-3.06	2.75-3.54
Fused (metallurgical)	2.45-3.06	2.75-3.35

	December 29 1975	December 31 1976
	($U.S.)	
Ferrovanadium, per lb of V, packed, fob shipping point		
Carvan	5.10	5.60
Ferovan	5.10	5.60

Tariffs

Canada

Item No.		British Preferential	Most Favoured Nation	General	General Preferential
32900-1	Vanadium ores and concentrates	free	free	free	free
37520-1	Vanadium oxide	free	free	5%	free
35101-1	Vanadium metal, ex-alloy	free	5%	25%	free
37506-1	Ferrovanadium	free	5%	5%	free

United States

Item No.		
601.60	Vanadium ores and concentrates	free
632.58	Vanadium metal, unwrought, waste and scrap (duty on waste and scrap suspended to June 30, 1978)	5%
632.68	Vanadium alloys, unwrought	7.5%
633.00	Vanadium metal, wrought	9%
607.70	Ferrovanadium	6%
422.60	Vanadium pentoxide (anhydride)	16%
422.58	Vanadium carbide	6%
427.22	Vanadium salts	16%
422.62	Other vanadium compounds	16%

Sources: The Customs Tariff and Amendments, Revenue Canada, Customs and Excise Division, Ottawa. Tariff Schedules of the United States Annotated (1976), TC Publication 749.

Zinc

D.H. BROWN

The year 1976 proved to be another recession year for the zinc industry throughout the world. Volumes improved by about one-third over 1975; however, despite this partial recovery, production remained modestly surplus to demand and the high stocks carried over from 1975 were still largely in place at year-end 1976, offset by some evidence of stock rebuilding by consumers. Competition for sales in the rising market was intense and price discounting became widespread during the year. Metal realizations declined despite the appearance of stability in published prices and industry profitability was again substantially eroded during the year.

In Canada mine production declined 6 per cent from 1975 while world mine production remained unchanged, and metal production, although higher in volume than 1975, represented only 74 per cent of capacity compared to 76 per cent on a world basis. Both these circumstances reflected not only Canada's dependence on the performance of export markets but also our vulnerability to stagnation in those markets. Accordingly, mine exports declined for the third consecutive year although metal exports increased substantially to pre-recession levels.

Mine production in Canada

The metal content of zinc concentrate mine output was 1 145 407 tonnes* in 1976 compared with 1 229 481 tonnes in 1975. Thirty principal mining enterprises contributed to Canada's zinc mine production in 1976 and a summary of their operations is listed in Table 6. All zinc mine production in Canada is produced in conjunction with lead, copper and silver. By ore classification, about 38 per cent comes from zinc ores, 13 per cent from copper ores, and the balance from mixed ores, as production from lead ores is negligible. On the same basis, approximately 30 per cent of copper mine production, 100 per cent of lead mine production, and 75 to 80 per cent of silver mine production are produced jointly with zinc.

Mill capacity at year-end 1976 was 96 300 tonnes of ore a day, including 1 950 tonnes a day of new capacity added during the year through Nanisivik Mines Ltd., Lemoine Mines Limited, and Northair Mines Ltd. coming into production. During 1976 the Hudson Bay Mining and Smelting Co., Limited closed the Schist Lake copper-zinc mine and the Sullivan Mining Group Ltd. gave formal notice to employees in early November announcing closure, effective January 31, 1977, of the company's copper-zinc-silver mining operations at the Cupra and D'Estrie mines in the Eastern Townships of Quebec. At year-end 1976, Consolidated Columbia River Mines Ltd., which operates the Ruth Vermont lead-zinc-silver mine, was placed in receivership and it is uncertain whether the mine will reopen in the spring of 1977 as originally planned.

Overall, Canadian zinc producing mines operated at 73.9 per cent of mill capacity and processed ores having an average zinc grade of 5.3 per cent. By comparison, mill capacity utilization in 1975 was 83.5 per cent and the average grade of ore was 5.1 per cent. The sharp decline in 1976 was due to extended strikes at Cyprus Anvil Mining Corporation and the Mining Division of Brunswick Mining and Smelting Corporation Limited. Average recovery of zinc in concentrate from ore increased to 83.7 per cent from 82.7 per cent the previous year. Typically the electrolytic refining of zinc in concentrate would recover 90 to 95 per cent of the zinc content in the form of refined metal. Employment in zinc producing mines which also produced lead and copper is estimated at 14 081 personnel at year-end 1976, down about 300 from peak staffs in 1975.

Newfoundland

Mill throughput at the Buchans mine operated by ASARCO Incorporated (formerly American Smelting and Refining Company) was down 22 000 tonnes to 188 700 tonnes, resulting in zinc-in-concentrate production declining to 16 200 tonnes in 1976 from 17 700 tonnes in 1975. Ore reserves at year-end were 550 000 tonnes grading 10.5 per cent zinc, 6 per cent lead, 1 per cent copper, 0.6 gram gold per tonne, and 85 grams silver per tonne, sufficient to continue the current level

*The term "tonne" refers to the metric ton of 2 204.62 pounds avoirdupois.

Table 1. Western world primary zinc statistics, 1974-77

	1974	1975	1976^p	1977^e
	(000 tonnes)			
Mine production (Zn content)	4 436	4 403	4 377	4 810
Metal production	4 363	3 759	4 070	4 200
Metal consumption	4 574	3 530	4 111	4 350
Refinery capacity	4 931	5 180	5 329	5 548
Refinery operating rate	89%	73%	76%	76%

Source: International Lead Zinc Study Group.
^{p} Preliminary; ^{e}Estimated by the Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

of operation a further three years. The mill, with a capacity of 1 150 tonnes per day, operates five days a week. The mine was leased from Terra Nova Properties Limited, a wholly-owned subsidiary of Price (Nfld.) Pulp & Paper Limited, under a 1928 agreement by which mine profits were shared jointly by the operator and the lease holder; however, that agreement was continued in 1976 under a 25-year agreement in which ASARCO assumes a 49 per cent interest in the joint venture and continues to operate the mine, and Price assumes a 51 per cent interest and takes on management of exploration.

Newfoundland Zinc Mines Limited, which is 63 per cent owned by Teck Corporation Limited and 37 per cent by AMAX Zinc (Newfoundland) Ltd., completed its first full year of operation at near-capacity production. The mill treated 474 200 tonnes grading 8.1 per cent zinc to produce 61 200 tonnes of zinc concentrate averaging 62 per cent zinc. The zinc content of concentrate was 38 000 tonnes compared with 14 200 tonnes in 1975. The mine commenced mill production June 29, 1975. Ore reserves were 3 448 000 tonnes grading 8.9 per cent zinc, after allowance for mining dilution.

Nova Scotia

The Gays River lead-zinc deposit held 60 per cent by Imperial Oil Limited and 40 per cent by Preuvier Mines Limited was reported to have an estimated 10.9 million tonnes of drill-indicated ore in 1974 grading about 5.6 per cent zinc and 2.3 per cent lead. The underground development program was completed in late 1976 and Imperial Oil Limited announced that the results were being evaluated for a decision on the commercial feasibility of the project. Company officials estimate that about 5.3 million tonnes grading 7 per cent combined zinc-lead are recoverable, allowing for 10 per cent dilution. Preussag Canada Limited, under an agreement with Cuvier Mines Ltd., financed the latter company's 40 per cent share of development expenses, amounting to $1.6 million by year-end 1976, but declined to invest further capital in the project. In return for this development financing, Preussag earned $1.9 million of 12 per cent debentures, 14.4 common shares out of 200 issued common shares in Preuvier Mines Limited, and 87 300 common shares of Cuvier Mines Ltd. Preuvier Mines Limited was created as a wholly-owned subsidiary of Cuvier Mines Ltd. to hold its 40 per cent interest in the deposit and become its financing vehicle.

Table 2. Canada, primary zinc statistics 1974-77

	1974	1975	1976^p	1977^e
	(000 tonnes)			
Mine production (Zn content)	1 240	1 229	1 145	1 260
Metal production	437	427	472	500
Metal consumption	137	120	125	125
Refinery capacity	557	563	636	636
Refinery operating rate	78%	76%	74%	79%
Exported mine production (A)	867	705	648	710
Exported metal production (B)	297	247	350	375
Export processing index				
(B ÷ (A+ B) x 100)	26%	26%	35%	35%

Source: Statistics Canada.
^{p}Preliminary; ^{e}Estimated by the Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.

Table 3. Canada, zinc production, trade and consumption, 1975-76

	1975		1976p	
	(tonnes)	($)	(tonnes)	($)
Production				
All forms[1]				
Ontario	335 852	277 660 498	320 030	265 426 000
New Brunswick	149 210	123 356 568	171 733	142 432 000
Northwest Territories	129 002	106 650 304	144 307	119 685 000
Quebec	125 241	103 541 200	122 934	101 960 000
British Columbia	99 669	82 399 493	113 266	93 940 000
Manitoba	64 045	52 948 124	61 935	51 367 000
Yukon	115 395	95 400 540	51 723	42 898 000
Newfoundland	32 198	26 619 174	45 616	37 833 000
Saskatchewan	4 539	3 752 357	8 144	6 755 000
Total	1 055 151	872 328 258	1 039 688	862 296 000
Mine output[2]	1 229 481	..	1 145 407	..
Refined[3]	426 941	..	472 316	..
Exports				
Zinc blocks, pigs and slabs				
United States	161 599	133 760 000	274 449	211 653 000
United Kingdom	56 406	43 365 000	40 491	29 349 000
Venezuela	3 544	2 924 000	6 347	4 239 000
Singapore	5 284	4 133 000	4 029	2 924 000
India	1 250	876 000	3 524	2 313 000
Pakistan	612	510 000	2 795	2 083 000
Turkey	1 391	1 102 000	2 077	1 461 000
Hong Kong	1 624	1 202 000	1 875	1 275 000
Thailand	280	206 000	1 586	1 117 000
Belgium and Luxembourg	4 651	4 033 000	1 681	1 106 000
Taiwan	840	596 000	1 583	1 073 000
South Korea	—	—	1 550	1 051 000
West Germany	2 325	1 763 000	1 245	902 000
Philippines	757	641 000	860	699 000
Guatemala	685	533 000	927	648 000
Malaysia	324	244 000	820	595 000
Other countries	5 708	4 713 000	4 648	3 399 000
Total	247 280	200 601 000	350 487	265 887 000
Zinc contained in ores and concentrates				
Belgium and Luxembourg	229 735	96 274 000	250 522	93 772 000
Japan	167 149	75 292 000	108 351	45 155 000
West Germany	100 841	37 401 000	111 625	38 629 000
United States	86 116	37 196 000	48 481	19 161 000
Italy	31 895	10 940 000	34 989	11 378 000
Poland	15 118	6 583 000	21 192	7 616 000
India	—	—	23 785	6 990 000
Netherlands	29 209	11 557 000	17 230	6 370 000
United Kingdom	3 229	1 342 000	9 149	3 332 000
France	19 735	9 180 000	7 889	3 118 000
South Africa	4 997	2 393 000	6 906	2 698 000
Other countries	17 121	5 920 000	8 031	2 495 000
Total	705 145	294 078 000	648 150	240 714 000

Table 3. (cont'd)

	1975		1976[p]	
	(tonnes)	($)	(tonnes)	($)
Zinc alloy scrap, dross and ash (gross weight)				
United States	10 690	1 821 000	10 872	1 805 000
United Kingdom	3 275	1 140 000	1 940	496 000
West Germany	830	233 000	1 546	282 000
France	336	75 000	749	168 000
Spain	224	108 000	306	167 000
Belgium and Luxembourg	319	62 000	320	75 000
Italy	144	72 000	104	65 000
Other countries	399	163 000	312	85 000
Total	16 217	3 674 000	16 149	3 143 000
Zinc dust and granules				
United States	2 011	2 179 000	3 295	3 344 000
Turkey	—	—	261	298 000
Nicaragua	7	9 000	5	6 000
United Kingdom	74	27 000	18	4 000
El Salvador	—	—	1	2 000
Other countries	66	97 000	—	—
Total	2 158	2 312 000	3 580	3 654 000
Zinc fabricated material nes				
United States	1 417	1 488 000	4 371	3 831 000
France	—	1 000	108	44 000
United Kingdom	213	210 000	32	37 000
Costa Rica	—	—	20	24 000
Mexico	17	6 000	2	6 000
Italy	—	—	2	4 000
Other countries	126	127 000	1	3000
Total	1 773	1 832 000	4 536	3 949 000
Imports				
In ores, concentrates and scrap	756	295 000	3 531	1 534 000
Dust and granules	116	147 000	185	231 000
Slabs, blocks, pigs and anodes	686	606 000	12 518	9 856 000
Bars, rods, plates, strip and sheet	240	395 000	262	405 000
Zinc oxide	1 479	1 189 000	1 808	1 454 000
Zinc sulphate	1 271	456 000	1 776	578 000
Zinc fabricated material nes.	855	1 778 000	1 172	2 598 000
Total	5 403	4 866 000	21 252	16 656 000

Table 3. (concl'd)

	1974r			1975		
	Primary	Secondary	Total	Primary	Secondary	Total
Consumption[4]						
Zinc used for, or in the manufacture of:						
Copper alloys (bronze brass, etc.)	14 096	..	..	8 376	..	..
Galvanizing: electro	2 193	666	73 702	2 102	418	64 559
hot dip	56 747			53 663		
Zinc die-cast alloy	16 140	—	16 140	9 928	—	9 928
Other products (including rolled and ribbon zinc, zinc oxide)	20 811	6 966	27 777	18 780	5 013	23 793
Total	109 987	7 632	117 619	92 849	5 431	98 280
Consumer stocks on hand at end of year	14 273	1 350	15 623	12 505	1 060	13 565

Source: Statistics Canada.
[1]New refined zinc produced from domestic primary materials (concentrates, slags, residues, etc.) plus estimated recoverable zinc in ores and concentrates shipped for export. [2]Zinc content of ores and concentrates produced. [3]Refined zinc produced from domestic and imported ores. [4]Consumer survey does not represent 100 per cent of Canadian consumption and is therefore consistently less than apparent consumption.
p Preliminary; .. Not available for publication; — Nil; nes Not elsewhere specified; r Revised.

New Brunswick

The expansion program at the No. 12 mine of Brunswick Mining and Smelting Corporation Limited continued on schedule, and at December 31, 1976 expenditures to date amounted to $28.2 million of a planned $53 million at completion in 1979. At that time the second underground shaft will be operational, raising the hoisting capacity of the mine to 9 900 tonnes a day from the current 5 900 tonnes a day. At year-end the new 1 380-metre shaft was 52 per cent complete. Zinc-in-concentrate production declined to 120 700 tonnes from 167 000 tonnes in 1975 owing to a labour strike during the period May 29 to August 28, 1976. The No. 6 mine will commence underground production in the first quarter of 1977 as open-pit reserves become exhausted. Reserves at No. 6 are 1 439 000 tonnes grading 6.99 per cent zinc, 2.53 per cent lead, 0.31 per cent copper and 76.8 grams of silver a tonne. Reserves at No. 12 are 95 158 000 tonnes above the 990-metre level grading 9.21 per cent zinc, 3.77 per cent lead, 0.32 per cent copper and 96.3 grams silver a tonne. Production at the No. 6 underground adit will be phased out to coincide with the expansion at the No. 12 mine, at which time overall production capacity will increase by about 35 per cent. In addition, the company reported that metallurgical research on the complex ores has been productive and should result in improved zinc recovery in 1977 from the 1976 level of 74.9 per cent.

Zinc-in-concentrate production at Heath Steele Mines Limited increased to 37 800 tonnes in 1976 from 30 100 tonnes in 1975 due to a combination of increased ore production, higher zinc grade and better recovery. Ore production from the open pit was exhausted by year-end 1976 and the new 991-metre No. 5 shaft is expected to be fully operational by April 1977. The new hoisting capacity will increase zinc-in-concentrate production to about 46 000 tonnes a year. Ore reserves at year-end were 28 850 000 tonnes grading 4.4 per cent zinc, 1.16 per cent copper, 1.52 per cent lead and 61.4 grams of silver a tonne.

Production at Nigadoo River Mines Limited declined to 4 100 tonnes from 5 100 tonnes zinc in concentrate in 1975. Ore reserves, which were 227 000 tonnes at year-end 1976 grading 2.92 per cent zinc, 3.24 per cent lead, 0.16 per cent copper and 117.9 grams of silver a tonne, should be exhausted in early 1978.

Texasgulf Inc. continued exploration and development work at its Half Mile Lake zinc-lead property in the Indian Falls area of Northumberland county; however, plans to sink an 850-metre shaft were deferred due to poor results from metallurgical testing.

Quebec

The Lake Dufault Division of Falconbridge Copper Limited decreased zinc-in-concentrate production to 12 500 tonnes in 1976 from 13 600 tonnes in 1975. Ore reserves at year-end were 1 282 000 tonnes grading 3.75 per cent copper and 4.80 per cent zinc, sufficient for another three years of operation. Shaft sinking at the Corbet zinc-copper deposit southwest of the Millenbach mine was completed to the level of 814 metres in 1976. Underground definition drilling in 1977 to determine the size and location of mineralized zones is necessary to establish the ultimate depth of the Corbet shaft and the size of the potential mining operation. No estimate of reserves has yet been released.

Louvem Mining Company Inc. a wholly-owned subsidiary of Quebec Mining Exploration Company (SOQUEM) purchased the Golden Manitou zinc-silver mine, mill, and concentrator near Val d'Or, Quebec from Manitou-Barvue Mines Limited as of August 31, 1976. The terms of sale resulted in Manitou-Barvue Mines Limited receiving $1 million in cash, $2.1 million in interest-bearing debentures and a production royalty of 82.67¢ a tonne on future production once 272 200 tonnes have been processed by the new owners. Prior to the sale, ore from the Louvem mine had been custom milled by the vendor. Zinc-in-concentrate production for the merged properties for all of 1976 was 17 700 tonnes compared with 16 700 tonnes in 1975. Ore reserves at year-end are estimated to be 1 724 000 tonnes at the Louvem division grading 7.29 per cent zinc, and 31.5 grams of silver a tonne; and at the Manitou division 670 000 tonnes grading 2.3 per cent zinc, 0.3 per cent lead, and 130 grams of silver a tonne.

Lemoine Mines Limited, a wholly-owned subsidiary of Patino Mines (Quebec) Limited which, in turn, is wholly owned by Patino N.V. of the Netherlands, completed underground development in 1975 as well as the 275-tonne-a-day milling plant and ancillary facilities at its property 25.7 kilometres southeast of Chibougamau. Mill tune-up commenced at year-end, and the mine went into production in early 1976, employing 128 personnel. Ore reserves at year-end 1976 were 530 000 tonnes grading 9.56 per cent zinc, 4.59 per cent copper, 4.3 grams of gold per tonne and 79 grams of silver per tonne. During the year 97 000 tonnes of ore were processed, producing about 7 000 tonnes of zinc in concentrate which were exported to the Netherlands.

The Mattagami property of Mattagami Lake Mines Limited produced 74 900 tonnes of zinc-in-concentrate compared to 79 000 tonnes in 1975. A deep exploration decline from the 265-metre level to the 610-metre level was underway at year-end 1976 to provide access for diamond drilling down to 1 220 metres. Ore reserves at December 31, 1976 had declined to 8 714 000 tonnes grading 7.1 per cent zinc, 0.58 per cent copper and 32.5 grams silver a tonne.

Orchan Mines Limited increased zinc-in-concentrate production from 15 000 tonnes in 1975 to 24 800 tonnes in 1976 due to higher grade ore and increased mill throughput. The Norita Division, which cost $6 million and took three years to develop, commenced production in 1976 at the rate of 900 tonnes a day and supplemented ore production from the main Orchan mine where ore reserves are declining. At year-end, ore reserves were 779 000 tonnes grading 6.4 per cent zinc, 0.8 per cent copper and 24 grams of silver a tonne at the Orchan mine, and 1 600 000 tonnes grading 6.3 per cent zinc, 0.6 per cent copper and 27 grams of silver a tonne at the Norita Division. Orchan, to provide for continuing utilization of its crushing, milling, and service facilities as the main mine becomes depleted of ore, reached agreement early in 1976 with Phelps Dodge Corporation of Canada, Limited to acquire and develop for production its marginal-grade base metal property in La Gauchetière Township, some 40 kilometres west of the Orchan mill. Drilling on the property, which is now the P.D. Division of Orchan, has indicated 1 402 000 tonnes averaging 4.5 per cent zinc, 0.9 per cent copper and 17 grams of silver per tonne. The site has been cleared for erection of a small mining plant, and excavations are being made for a decline to develop the upper part of the ore zone for initial production by late 1978, and to establish the collar for a vertical shaft to develop and explore the zone in depth. It is estimated that expenditures totalling some $9 million, of which $815 000 was spent during the year, will be required to establish a production capacity of 725 tonnes of ore per day and continuity of employment for the Orchan work force.

Table 4. Canada, mine output, zinc, 1975-1976

	1975	1976
	(tonnes)	
Newfoundland	34 525	55 107
New Brunswick	197 505	160 221
Quebec	122 597	135 893
Ontario	398 077	373 003
Manitoba-Saskatchewan	75 401	80 481
British Columbia	113 140	109 493
Yukon Territory	127 035	66 409
Northwest Territories	161 201	164 406
Total	1 229 481	1 145 013

Source: Statistics Canada.

Ontario

The Sturgeon Lake Joint Venture, operated by Falconbridge Copper Limited, increased zinc-in-concentrate production to 24 000 tonnes in 1976 from 22 500 tonnes in 1975; however, milling problems continued due to oxidation and alteration of ore near fault zones in the orebody and resulted in recovery of about two-thirds of the zinc in the zinc concentrate. Modifications have been made to the mining sequence to treat the more favourable ore first, leaving the refractory ore types to a time when research has developed better methods to handle this ore. The joint venture includes Falconbridge Copper Limited with a 13.4 per cent interest, NBU Mines Limited with a 6.6 per cent interest, and Sturgeon Lake Mines Limited with an 80 per cent interest, and becomes effective once the capital development costs have been recovered. The last company is 67 per cent owned by Falconbridge Copper Limited and 33 per cent by NBU Mines Limited. Ore reserves at year-end 1976 were reported at 1 234 000 tonnes grading 9.06 per cent zinc, 3.01 per cent copper, 1.1 per cent lead and 188 grams of silver a tonne.

Zinc-in-concentrate production at Mattabi Mines Limited, which is owned 60 per cent by Mattagami Lake Mines Limited and 40 per cent by the Abitibi Paper Company Ltd., increased to 69 000 tonnes in 1976 from 62 500 tonnes in 1975. The underground development declines have been completed for ventilation and access purposes but work has stopped temporarily pending assessment of additional underground drilling. Ore reserves were reduced 34 per cent to 5 897 000 tonnes at year-end 1976 grading 6.89 per cent zinc, 0.7 per cent copper, 0.68 per cent lead and 92 grams of silver a tonne, due to tonnage already milled, and a reinterpretation of deeper ore lenses following underground diamond drilling. The Lyon Lake Division of Mattagami Lake Mines Limited completed shaft sinking and services in 1976, with lateral development, stope preparation and crusher installation scheduled for 1977, during which time batches of development ore will be run through the Mattabi Mines Limited concentrator to determine the milling characteristics. Ore reserves remained unchanged at 3 656 000 tonnes grading 6.66 per cent zinc, 1.15 per cent copper, 0.63 per cent lead and 116 grams of silver a tonne.

The Geco Division of Noranda Mines Limited reported a decline in zinc-in-concentrate production to 35 200 tonnes in 1976 from 47 000 tonnes in 1975. Ore reserves at year-end 1976 were 24 948 000 tonnes grading 1.87 per cent copper, 3.59 per cent zinc and 51 grams of silver a tonne.

The South Bay Division of Selco Mining Corporation Limited reported that zinc-in-concentrate production remained unchanged from the prior year at 15 700 tonnes. Ore reserves at year-end 1976 increased to 615 000 tonnes grading 10.82 per cent zinc, 1.71 per cent copper, and 72 grams of silver a tonne, with the discovery of the No. 12 ore zone below the 275-metre level.

The Kidd Creek mine, wholly-owned by Texasgulf Canada Ltd. (formerly Ecstall Mining Limited), a subsidiary of Texasgulf Inc. produced 225 000 tonnes of zinc in concentrate in 1976 compared with 251 100 tonnes in 1975. A $100-million expansion program is designed to increase mine production and processing of ore to 4.5 million tonnes a year in 1978-79 by the addition of the 1 615-metre No. 2 shaft which was 83 per cent complete at year-end 1976, and a fourth circuit to the concentrator, for which construction remained on schedule. Because the metal content of underground ore increases with depth in the case of copper and decreases in the case of zinc, zinc-in-concentrate production is not expected to increase as a result of this expansion. However, some zinc-rich ore is found at greater depth and this will be mined in the future. Production of ore from the open pit will cease in 1977 as the underground operation comes to full capacity. Ore reserves at year-end 1976 above the 853-metre level were 80 741 000 tonnes grading 6.8 per cent zinc, 2.73 per cent copper, 0.22 per cent lead, and 79 grams of silver a tonne.

The Manitouwadge Division of Willroy Mines Limited produced 10 500 tonnes of zinc in concentrate compared to 10 000 tonnes in 1975. Ore reserves at year-end 1976 were reported at 689 000 tonnes grading 4.42 per cent zinc, 0.28 per cent copper and 50 grams of silver a tonne; however, it was announced that the mine would cease operation in the first quarter of 1977 once the crown pillar of the Big Nama Creek mine was depleted because operations based solely upon ore from the Willecho mine would not be economic.

Manitoba and Saskatchewan

Hudson Bay Mining and Smelting Co., Limited in Flin Flon, Manitoba treated ore produced by the Flin Flon,

(text continued on page 621)

Table 5. Canada, zinc production, exports and consumption, 1965, 1970, 1974-76

	Production		Exports			Consumption[3]
	All Forms[1]	Refined[2]	In ores and concentrates	Refined	Total	
	(tonnes)					
1965	745 738	325 224	442 203	239 678	681 881	85 090
1970	1 135 714	413 196	809 248	318 834	1 128 082	95 836
1974	1 127 008	437 725	866 698	296 777	1 163 475	109 987[r]
1975	1 055 151	426 941	705 145	247 280	952 425	92 849
1976[p]	1 039 688	472 316	648 150	350 487	998 637	. .

Source: Statistics Canada.
[1]New refined zinc produced from domestic primary materials (concentrates, slags, residues, etc.) plus estimated recoverable zinc in ores and concentrates shipped for export. [2]Refined zinc produced from domestic and imported ores. [3]Refined primary zinc only reported by consumers; however, consumer survey does not represent 100 per cent of Canadian consumption and therefore is consistently less than apparent consumption.
[p]Preliminary; [r]Revised; . . Not available.

Table 6. Principal zinc mines in Canada 1976 and (1975)

Company and Location	Mill capacity	Zinc	Lead	Copper	Silver	Ore produced	Zinc concentrate produced	Grade of zinc in concentrate	Contained[1] zinc produced	Destination[2] of zinc concentrate
	(tonnes per day)	(%)	(%)	(%)	(grams per tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Newfoundland										
ASARCO Incorporated, Buchans	1 150 (1 150)	10.69 (10.54)	6.03 (5.92)	0.96 (0.95)	105.6 (103.98)	188 694 (210 466)	29 134 (32 008)	55.6 (55.16)	18 674 (20 502)	6,8,9,11 (8,9,11,12)
Newfoundland Zinc Mines Limited, Daniel's Harbour	1 350 (1 350)	8.1 (6.3)	– (–)	– (–)	– (–)	474 199 (220 580)	61 213 (22 669)	62.0 (62.5)	37 998 (14 187)	3,6 (3,6)
New Brunswick										
Brunswick Mining and Smelting Corporation Limited, Bathurst	8 950 (8 950)	7.01 (7.11)	2.80 (2.95)	0.37 (0.40)	84.3 (86.7)	2 247 212 (3 109 140)	231 839 (321 446)	52.04 (51.95)	120 707 (166 991)	9 (9)
Heath Steele Mines Limited, Newcastle	3 650 (2 800)	4.53 (3.99)	1.85 (1.54)	0.99 (1.03)	77.8 (59.3)	1 052 568 (988 326)	72 422 (58 372)	48.34 (47.99)	37 818 (30 136)	8,9,12 (8,9,12)
Nigadoo River Mines Limited, Bathurst	1 050 (1 050)	2.63 (2.69)	2.43 (2.55)	0.16 (0.25)	93.9 (117.9)	198 698 (231 403)	8 970 (9 579)	45.30 (44.96)	4 063 (5 073)	9 (9)
Quebec										
Falconbridge Copper Limited, Lake Dufault Division, Noranda	1 400 (1 400)	3.44 (3.35)	– (–)	3.09 (2.50)	41.5 (38.4)	458 447 (508 727)	23 523 (25 837)	52.82 (52.65)	12 529 (13 602)	8 (8)

Lemoine Mines Limited, Lemoine Mine, Chibougamau	350 (—)	10.4 (—)	— (—)	4.35 (—)	87.7 (—)	88 239 (—)	13 067 (—)	53.22 (—)	6 955 (—)	8 (—)
Louvem Mining Company Inc.[3] Louvicourt	— (—)	5.99 (—)	. . (..)	— (..)	56.22 (..)	258 534 (136 502)	28 380 (30 811)	54.57 (55.83)	15 110 (13 933)	12 (12)
Manitou-Barvue Mines Limited,[3] Val d'Or	1 450 (1 450)	3.13 (1.88)	0.51 (0.30)	— (—)	97.0 (81.9)	96 836 (222 255)	.. (5 226)	.. (52.8)	2 616 (2 762)	(6) (6)
Mattagami Lake Mines Limited, Mattagami	3 500 (3 500)	7.3 (7.3)	0.10 (—)	0.55 (0.62)	31.9 (29.5)	1 112 156 (1 166 370)	140 513 (147 179)	52.7 (53.1)	74 900 (79 032)	3,12 (3)
Orchan Mines Limited, Orchan & Garon Lake mines Matagami	1 700 (1 700)	6.74 (4.65)	— (—)	0.78 (1.19)	31.9 (16.5)	424 260 (382 655)	48 064 (28 717)	51.64 (52.09)	24 818 (14 959)	3 (3)
Sullivan Mining Group Ltd.,										
Stratford Centre[4]	1 300	2.32	0.51	2.54	38.3	207 485	..	..	3 877	6
Cupra Division	(1 300)	(4.12)	(0.47)	(2.24)	(33.3)	(50 855)	(3 024)	(56.58)	(1 711)	(6)
D'Estrie Mining Company Ltd.	(—)	(2.12)	(0.54)	(2.57)	(38.3)	(163 379)	(5 009)	(56.49)	(2 830)	(6)
Ontario										
Falconbridge Copper Limited, Sturgeon Lake Joint Venture, Sturgeon Lake	1 100 (1 100)	9.57 (9.07)	1.23 (1.17)	2.15 (2.78)	183.8 (182.1)	377 257 (341 720)	46 019 (42 825)	52.29 (52.44)	24 064 (22 456)	12 (12)
Mattabi Mines Limited, Sturgeon Lake	2 700 (2 700)	8.13 (7.34)	0.76 (0.70)	1.23 (0.97)	121.0 (110.7)	966 797 (975 154)	126 185 (116 022)	54.36 (53.69)	69 016 (62 472)	3,12 (6,12)
Noranda Mines Limited, Geco Division, Manitouwadge	4 550 (4 550)	2.55 (3.54)	0.12 (0.20)	1.69 (1.84)	44.2 (49.4)	1 529 781 (1 450 891)	56 584 (76 331)	52.07 (52.84)	35 193 (47 132)	3 (3)

Table 6. (cont'd)

Company and Location	Mill capacity	Zinc	Lead	Copper	Silver	Ore produced	Zinc concentrate produced	Grade of zinc in concentrate	Contained[1] zinc produced	Destination[2] of zinc concentrate
	(tonnes per day)	(%)	(%)	(%)	(grams per tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Ontario (cont'd)										
Selco Mining Corporation Limited, South Bay Division, Uchi Lake	450 (450)	10.38 (11.18)	— (—)	1.73 (1.82)	79.9 (..)	163 482 (152 713)	29 181 (28 657)	53.66 (54.46)	15 658 (15 608)	6 (6)
Texasgulf Inc., Kidd Creek mine, Timmins	9 050 (9 050)	8.05 (8.20)	0.30 (0.25)	1.73 (1.71)	119.7 (106.3)	3 242 279 (3 630 224)	429 099 (457 900)	51.98 (51.49)	224 955 (251 122)	7,12 (6,7,12)
Willroy Mines Limited, Manitouwadge Div. Manitouwadge[5]	1 450 (1 300)	3.67 (3.82)	0.17 (0.22)	0.56 (0.42)	54.5 (53.5)	311 430 (296 970)	20 482 (19 018)	51.58 (52.6)	10 503 (9 985)	6 (3)
Manitoba and Saskatchewan										
Hudson Bay Mining and Smelting Co., Limited										
Centennial	—	2.1	—	1.3	20.6	55 979	na	na	na	na
Flin Flon	7 700	2.2	—	1.7	24.0	679 195	na	na	na	na
Osborne Lake	—	1.9	—	3.1	6.9	175 757	na	na	na	na
Stall Lake	—	0.2	—	4.1	10.3	186 793	na	na	na	na
White Lake	—	4.7	—	1.9	24.0	50 070	na	na	na	na
Ghost Lake	—	10.1	0.5	1.2	54.9	31 747	na	na	na	na
Schist Lake	—	6.0	—	3.0	30.9	13 898	na	na	na	na
Anderson Lake	—	0.1	—	3.3	10.3	117 681	na	na	na	na
Chisel Lake	—	10.8	0.5	0.8	41.1	106 322	na	na	na	na
Flin Flon	7 700 (7 700)	2.7 (3.0)	0.2 (0.2)	2.3 (2.4)	20.6 (20.6)	1 417 442 (1 333 704)	50 039 (49 565)	47.7 (48.6)	31 191 (30 569)	2 (2)

Sherritt Gordon Mines Limited, Fox Mine, Lynn Lake	2 700 (2 600)	1.68 (1.81)	— (—)	1.56 (1.74)	.. (..)	755 123 (913 701)	17 354 (20 404)	49.41 (48.35)	10 348 (12 672)	2 (2)
Ruttan Mine, Ruttan Lake	9 050 (9 050)	2.14 (1.90)	— (—)	1.08 (0.96)	.. (..)	2 413 868 (3 030 718)	83 523 (88 883)	50.56 (50.12)	44 455 (48 130)	2,6,7 (2,7)
British Columbia										
Cominco Ltd., Sullivan Mine, Kimberley	9 050 (7 250)	3.95 (4.16)	4.0 (3.85)	— (—)	45.9 (43.5)	2 124 892 (2 002 927)	150 648 (148 783)	48.1 (47.7)	77 007 (75 368)	1 (1)
H.B. Mine, Salmo	1 100 (1 100)	3.82 (3.40)	0.69 (0.56)	— (—)	.. (..)	374 803 (411 086)	23 261 (22 884)	53.8 (53.2)	12 877 (12 700)	1 (1)
Consolidated Columbia River Mines Ltd.[4] Ruth Vermont Mine, Golden	300 (300)	.. (..)	.. (..)	.. (..)	.. (..)	42 000 (10 258)	1 500 (342)	55.0 (52.50)	825 (215)	1 (1)
Kam-Kotia Mines Limited, Silmonac mine, Sandon	100 (100)	4.86 (4.82)	5.3 (5.66)	— (—)	457.7 (599.3)	16 694 (10 927)	1 240 (757)	49.54 (51.21)	744 (471)	6 (6)
Northair Mines Ltd., Alta Lake, Brandywine area	250 (—)	1.81 (—)	0.86 (—)	— (—)	111.8 (—)	47 555 (—)	846 (—)	48.5 (—)	411 (—)	2 (—)
Teck Corporation Limited, Beaverdell Mine, Beaverdell	100 (100)	0.54 (0.39)	0.43 (0.38)	— (..)	336.3 (318.8)	34 448 (34 898)	298 (239)	39.06 (38.12)	186 (136)	1 (1)
Western Mines Limited, Lynx and Myra Falls	1 000 (1 000)	7.73 (7.59)	1.42 (1.42)	1.19 (1.12)	169.4 (153.9)	269 294 (260 719)	32 299 (31 222)	52.85 (52.4)	18 987 (18 091)	12 (6,9)

Table 6. (concl'd)

Company and Location	Mill capacity	Zinc	Lead	Copper	Silver	Ore produced	Zinc concentrate produced	Grade of zinc in concentrate	Contained[1] zinc produced	Destination[2] of zinc concentrate
	(tonnes) per day)	(%)	(%)	(%)	(grams per tonne)	(tonnes)	(tonnes)	(%)	(tonnes)	
Yukon Territory										
Cyprus Anvil Mining Corporation, Faro	9 050 (9 050)	5.48 (5.41)	2.66 (4.03)	— (—)	16.5 (..)	1 519 881 (2 925 874)	114 868 (209 101)	51.36 (50.80)	72 890 (133 471)	7,8 (7)
Also bulk lead-zinc concentrate							24 622 (69 957)	28.94 (29.34)	included above	8 (7,8)
United Keno Hill Mines Limited, Elsa	450 (450)	1.17 (1.15)	4.02 (4.03)	— (—)	1 216.8 (1 128.7)	68 506 (82 427)	586 (556)	48.0 (51.53)	282 (287)	2 (6)
Northwest Territories										
Pine Point Mines Limited, Pine Point	9 050 (9 050)	5.3 (4.88)	1.7 (2.37)	— (—)	— (—)	3 422 833 (3 542 268)	295 711 (273 468)	57.37 (57.93)	171 277 (161 201)	1,6,7,8,9,12 (1,6,12)
Nanisivik Mines Ltd.[5], Baffin Island	1 350 (—)	14.5 (—)	2.9 (—)	— (—)	.. (—)	70 762 (—)	14 756 (—)	49.0 (—)	7 230 (—)	12 (—)

[1]Total zinc contained in all concentrates. [2]Destination of concentrates: (1) Trail; (2) Flin Flon; (3) Valleyfield; (4) Belledune; (5) Timmins; (6) U.S.A.; (7) Japan; (8) Germany; (9) Belgium; (10) France; (11) Britain; (12) Unspecified and other countries. [3]Merged production on August 11, 1976. [4]Estimated from reports in the technical press. [5]1976 production stockpiled for shipment in 1977.

— Nil; .. Not available; na Not applicable.

Table 7. Prospective zinc-producing mines in Canada

Company and Location	Year Production Expected	Mill or Mine Capacity	Indicated Ore Reserves	Grade of Ore: Zinc	Grade of Ore: Lead	Grade of Ore: Copper	Grade of Ore: Silver	Remarks
		(tonnes ore/ day)	(tonnes)	(%)	(%)	(%)	(grams/ tonne)	
Nova Scotia								
Imperial Oil Limited, Gays River deposit, Gays River	1979	..	10 900 000	5.6	2.3	—	..	Optioned from Cuvier Mines Ltd. Feasibility study due 1977.
Quebec								
Noranda Mines Limited,								
Magusi Mine	..	1 350	1 407 000	3.5	—	1.2	31	Copper zone. Under study.
	..	..	425 000	8.3	—	0.3	—	Zinc zone. Under study.
West MacDonald Mine	1979	..	1 996 000	5.6	—	0.1	31	Under study.
Orchan Mines Limited,								
P.D. Div., LaGauchetiere	1978	725	1 402 000	4.5	—	0.9	17	Under construction.
Barvue Mine, Barraute	..	2 250	3 200 000	3.5	—	—	34	Construction awaiting improved market conditions.
Selco Mining Corp. Ltd., Pickands Mather & Co., Detour deposit, Brouillan	1982-85	..	31 300 000	2.3	—	0.39	36	"A" zone on surface. Underground study due 1978.
			3 100 000	0.8	—	4.49	39	"B" zone underground above 275 metres.
Ontario								
Mattagami Lake Mines Limited, Lyon Mine, Sturgeon Lake	1977	900	3 700 000	6.66	0.63	1.15	116	Ore to be processed at Mattabi Mines Ltd.

Table 7. (concl'd)

Company and Location	Year Production Expected	Mill or Mine Capacity	Indicated Ore Reserves	Grade of Ore Zinc	Grade of Ore Lead	Grade of Ore Copper	Grade of Ore Silver	Remarks
		(tonnes ore/ day)	(tonnes)	(%)	(%)	(%)	(grams/ tonne)	
Manitoba								
Hudson Bay Mining and Smelting Co., Limited, Snow Lake area, Westarm mine	1977	..	700 000	0.6	—	4.63	..	Shaft to 580 metre level by December 1976.
British Columbia								
Noranda Mines Limited, Goldstream deposit	1982	..	3 175 000	3.24	—	4.49	21	Feasibility study due 1977.
Yukon Territory								
Kerr Addison Mines Limited, Grum deposit, Vangorda Creek	1981	5 000	26 100 000	6.43	4.07	—	62	Final feasibility study due 1977.
Canex Placer Limited, Howards Pass Summit Lake	1985	..	270 000 000	About 5-10% Pb+Zn				Exploration and drilling to continue in 1977. An 80-kilometre access road is being constructed.
Hudson Bay Mining and Smelting Co., Limited, Tom deposit, MacMillan Pass	..	..	7 850 000	8.4	8.1	—	94	Underground work concluded in 1972. Further development is planned.

Northwest Territories								
Arvik Mines Ltd., Little Cornwallis Island	1981-85	..	22 700 000	14.1	4.3	..	34	Feasibility studies concluded. Mining decision subject to negotiations with the federal government.
Western Mines Ltd., Du Pont of Canada Exploration Limited, Pine Point	..	..	2 540 000	11.9	4.1	—	..	Further exploration and diamond drilling is planned for 1977.

Sources: Company reports, technical press and estimates by Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
— Nil; .. Not available.

Table 8. Indicated zinc deposits under exploration in Canada

Company and Location	Indicated Ore Tonnage	Grade of Ore: Zinc	Lead	Copper	Silver	Remarks
	(tonnes)	(%)	(%)	(%)	(grams/ tonne)	
New Brunswick						
Anaconda Canada Limited, Bathurst, Caribou property	45 360 000	4.48	1.7	0.47	59	In temporary production 1971 and 1974. Feasibility studies continue on bringing this property into production.
Chester Mines Limited, Newcastle	1 450 000	2.12	0.83	0.63	..	Ore available for open-pit mining.
	3 000 000	—	—	0.82	—	
	11 800 000	—	—	0.77	..	Ore available for underground mining. Feasibility study completed in 1970, and metallurgical testing continued in 1976.
Key Anacon Mines Limited, Bathurst	1 800 000	5.87	2.18	0.24	79	Mine partly developed. Re-evaluation of property in 1970 led to decision to defer placing the property into production at that time.
Canex Placer Limited, Portage Lakes area, Restigouche property	2 700 000	6.0	4.5	..	86	Partly recoverable by open pit. Further exploration in 1977.
Murray-Brook property	21 400 000	About 3% Pb+Zn				Further exploration in 1977.
Texasgulf Inc., Half Mile Lake	6 200 000	6.5	2.5	..	..	Plans to sink exploratory shaft deferred, but diamond drilling to continue in 1977.
Quebec						
Selco Mining Corporation Limited, Frotet Lake	1 328 000	2.96	—	1.73	38	Reserves insufficient to support capital investment for mining operations.

Ontario						
Giant Yellowknife Mines Limited, Errington and Vermilion Lake mines, Sudbury area	4 008 000 and 8 200 000	3.9 3.82	1.0 0.99	1.33 1.14	55 54	Extensive underground development in 1961-67 period. Ore difficult to concentrate. Reserves only for underground explored areas with low pyrite and high pyrite ore, respectively.
Manitoba						
Stall Lake Mines Limited, Snow Lake	610 000	2.28	..	5.38	..	Optioned to Falconbridge Nickel Mines Limited in 1965. Exploration completed in 1971. Property idle.
Saskatchewan						
Prairie West Explorations Ltd., Mackenzie deposit, Brabant Lake	3 928 000	4.43	..	0.64	..	Bison Petroleum & Minerals Limited has 40 per cent interest. Further work is planned.
British Columbia						
Barrier Reef Resources Ltd., Robb Lake	5 530 000	About 7.3% Pb+Zn				Drilling discontinued in 1976.
Yukon Territory						
Kerr Addison Mines Limited, Swim Lake deposit, Vangorda Creek	4 500 000	5.5	4.0	..	52	"A" group claims.
Vangorda Mines Limited, Vangorda Creek	8 500 000	4.96	3.18	0.27	60	Feasibility study made. No further exploration.
Barrier Reef Resources Ltd., Goz Creek, Bonnet Plume area	10 900 000	8.0	..	..	..	Drilling discontinued in 1976. Exploration expenses amounted to $1.2 million in 1972-75 period, and ore is sub-economic.
Northwest Territories						
Buffalo River Exploration Limited	1 350 000	9.6	3.4	—	..	Feasibility study for joint production with Coronet Mines Ltd. completed in 1971. Decision made not to put the property into production.
Welcome North Mines Ltd., Bear Property, Godin Lake	18 150 000	About 7-8% Pb+Zn			17-34	Drilling to continue in 1977.

Table 8. (concl'd)

Company and Location	Indicated Ore Tonnage	Grade of Ore Zinc	Lead	Copper	Silver	Remarks
	(tonnes)	(%)	(%)	(%)	(grams/ tonne)	
Western Mines Limited, Pine Point	2 540 000	11.9	4.1		..	X-25 deposit. A joint venture with Du Pont of Canada Exploration Limited. Further drilling planned for 1977.
Bathurst Norsemines Ltd, Hackett River, Bathurst Inlet area	19 500 000	4.98	0.75	0.41	150	Optioned to Cominco. Large deposit in three zones with high zinc and silver values. Under active exploration from 1970 and $2 million expended to December 1975. Wright Engineers performed $100 000 feasibility study in 1976 but results not yet announced.
Texasgulf Inc., Izok Lake	11 000 000	13.8	1.4	2.8	70	Central ore zone which is open to east. Remaining two zones not delineated and drilling to continue in 1977.
No. 10 Hood River	454 000	3.5	..	5.0	34	Development dependent upon Izok Lake.
No. 41 Hood River	272 000	4.12	..	1.57	18	

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
.. Not available; — Nil.

Osborne Lake, Stall Lake, White Lake, Ghost Lake, Schist Lake, Anderson Lake, Chisel Lake and Centennial mines during 1976 to produce 31 200 tonnes of zinc in concentrate compared to 30 600 tonnes in 1975. Operations at Schist Lake ceased March 1976 due to exhaustion of ore and the Dickstone mine which was closed August 1975 due to low metal prices remained inoperative throughout 1976. The Centennial copper-zinc mine, which is still under development, produced 56 000 tonnes of ore during the year and will reach full capacity during 1977. The shaft at the Westarm mine was completed to 580 metres and production is scheduled to commence in September 1977. Combined ore reserves for the nine mines at December 31, 1976 were 15 908 000 tonnes grading 2.66 per cent copper, 2.9 per cent zinc, and 19 grams of silver a tonne.

Zinc-in-concentrate production reported by Sherritt Gordon Mines Limited declined at both the Fox and Ruttan mines to 10 300 tonnes and 44 500 tonnes, respectively. At the Fox mine, operations were reduced to a five-day week in March 1976, which accounted for the lower mill throughput. At Ruttan, rehabilitation of equipment for the open pit and increased hauling distances contributed to the lower production of ore. Ore reserves at Fox declined to 7 109 000 tonnes grading 1.95 per cent copper and 2.1 per cent zinc. At Ruttan, reserves were reduced to 29 073 000 tonnes grading 1.73 per cent copper, and 1.25 per cent zinc due to some 6 000 000 tonnes of low-grade underground ore having been reclassified as sub-economic.

British Columbia

The Sullivan and H.B. mines owned by Cominco Ltd. continued production at the 1975 levels in 1976 with zinc-in-concentrate production amounting to 77 000 tonnes and 12 900 tonnes respectively. Ore reserves at the two mines are reported as 51 700 000 tonnes grading 10.88 per cent combined zinc and lead in the ratio of about 1.25 to 1.0.

The Ruth Vermont mine operated by Consolidated Columbia River Mines Ltd. was in production during the full second half of 1976 before being placed into receivership at year-end. Zinc-in-concentrate production was 825 tonnes and ore reserves at closing were estimated to be 1 200 000 tonnes, of which 200 000 tonnes were proven, grading 5.53 per cent zinc, 5.03 per cent lead and 100 grams of silver a tonne.

The Silmonac mine of Kam-Kotia Mines Limited produced 744 tonnes of zinc in concentrate. The zinc concentrate averaged 49.54 per cent zinc, 0.37 per cent cadmium and 2 123 grams of silver a tonne.

Similarly the Beaverdell mine of Teck Corporation Limited operated on a salvage basis during 1976 and produced 186 tonnes of zinc in concentrate. The zinc concentrate averaged 39.06 per cent zinc, 0.39 per cent cadmium and 1 580 grams of silver a tonne.

Zinc-in-concentrate production at the Lynx and Myra Falls mines operated by Western Mines Limited increased slightly to 19 000 tonnes in 1976. Ore reserves at year-end were 1 546 000 tonnes grading 7.9 per cent zinc, 1.2 per cent copper, 1.2 per cent lead, 3.1 grams of gold a tonne and 144 grams of silver a tonne.

Northair Mines Ltd. (N.P.L.) commenced tune-up at its Brandywine Falls silver-gold-lead-zinc property on May 1, 1976 and started full production September 1, 1976. Zinc-in-concentrate production amounted to 411 tonnes, and reserves at the end of the fiscal year amounted to 300 000 tonnes grading 4.06 per cent zinc, 2.72 per cent lead, 13.6 grams of gold a tonne and 156 grams of silver a tonne. At capacity, the mine is expected to produce about 1 500 tonnes of zinc in concentrate annually.

Table 9. Canadian primary zinc metal production, 1976

	Refined Zinc Production	Annual Rated Capacity	Per cent Utilization
	(tonnes)	(tonnes)	
Canadian Electrolytic Zinc Limited, Valleyfield, Que.	114 125	205 000	55.7
Cominco Ltd., Trail, B.C.	203 213	249 500	81.4
Hudson Bay Mining & Smelting Co. Ltd., Flin Flon, Man.	54 822	74 400	73.7
Texasgulf Canada Ltd., Hoyle, Ont.	97 705	108 900	89.7
Total	469 865	637 800	73.7

Sources: 1976 Company Annual Reports. *Metallurgical Works in Canada, Nonferrous and Precious Metals,* Operators List 3, January 1976, Department of Energy, Mines and Resources.

Yukon Territory

Cyprus Anvil Mining Corporation produced 72 900 tonnes of zinc in concentrate in 1976 compared with 133 700 tonnes in 1975. The substantial decline was due to three labour disputes during the year that reduced the number of milling days from 365 to 157. During the process of contract negotiations the mine and mill workers who form Local 1051 of the United Steelworkers of America went on strike from January 31 to February 12, at which point a new contract was ratified. The mine was struck again between March 29 and May 3 when Local 8243 of the same union, representing the office and technical workers, were negotiating a separate labour agreement, but this second strike was settled at parity with the terms achieved by Local 1051. On July 30 both locals went on strike when the Anti-Inflation Board substantially reduced the contractual increases in wage levels. The last strike continued until November 23, when revised labour agreements were ratified. Ore reserves were reported as 40 552 000 tonnes grading 8.6 per cent combined zinc and lead, and about 34 grams of silver a tonne. The ratio of zinc to lead is about 1.7 to 1.0.

Zinc-in-concentrate production at United Keno Hill Mines Limited was 282 tonnes in 1976, unchanged from 1975. Ore reserves at year-end were 165 000 tonnes grading 4.6 per cent lead, 1.2 per cent zinc, and 1 474 grams of silver a tonne.

Northwest Territories

Zinc-in-concentrate production at Pine Point Mines Limited increased to 171 300 tonnes from 161 200 tonnes in 1975. Six open pits were in production during the year, however, one was closed due to ore exhaustion. Three new pits were stripped of overburden in 1976, with one commencing production by year-end. A new 30-cubic-yard dragline has been ordered to commence high-volume low-cost stripping in 1979 of overburden covering deeper-seated ore deposits on the western part of the property. Ore reserves at year-end were 32 841 000 tonnes grading 5.4 per cent zinc and 2 per cent lead.

Nanisivik Mines Ltd. commenced production at its zinc-lead-silver operation at Strathcona Sound, Baffin Island in late September 1976. By agreement with the federal government, operating mill capacity is 1 350 tonnes a day. Reserves are estimated to be 6 260 000 tonnes averaging 14.1 per cent zinc, 1.4 per cent lead, and 50.7 grams of silver per tonne. During the first year of operation, the company plans to mine a zinc-rich section of ore, but production thereafter should return to normal levels of approximately 118 000 tonnes a year of zinc concentrate containing about 60 per cent zinc, 0.23 per cent cadmium, and 248 to 280 grams of silver per tonne, and approximately 9 000 tonnes a year of lead concentrate containing about 65 to 70 per cent lead and 31 to 62 grams of silver per tonne. Due to severe winter conditions, concentrates can be shipped from Strathcona Sound from July to September only. Accordingly, production in 1976, which amounted to 7 200 tonnes of zinc in concentrate, will not be exported until mid-1977. Construction costs for the mine complex are expected to be about $66 million, with $56.9 million spent by year-end 1976. Completion of the townsite airport and road construction is scheduled for 1977. Excluding construction personnel, the mine employs 150 persons, of whom approximately 30 per cent are Inuit. Currently, ownership of the mine is divided, with Mineral Resources International Limited holding 59.5 per cent, Metallgesellschaft A.G. in Germany and Billiton B.V. in the Netherlands each holding 11.25 per cent and the federal government of Canada holding 18 per cent. Texasgulf Inc. retains a 35 per cent carried interest in the property, as original owner, once all development costs have been recovered.

Metal production in Canada

Production of refined primary zinc metal in Canada during 1976 was 472 316 tonnes compared with 426 941 tonnes in 1975. Nearly 80 per cent of refined production was in High Grade (HG) and Special High Grade (SHG) forms, with the balance being Prime Western (PW) or Good Ordinary Brand (GOB), as it is known overseas. Collectively, Canadian zinc metal producers operated at 74 per cent of capacity during 1976 owing to reduced demand for metal. In the same period, physical stocks of zinc metal declined from 89 700 tonnes at year-end 1975 to 62 000 tonnes at year-end 1976. Metal production was distributed as shown in Table 9.

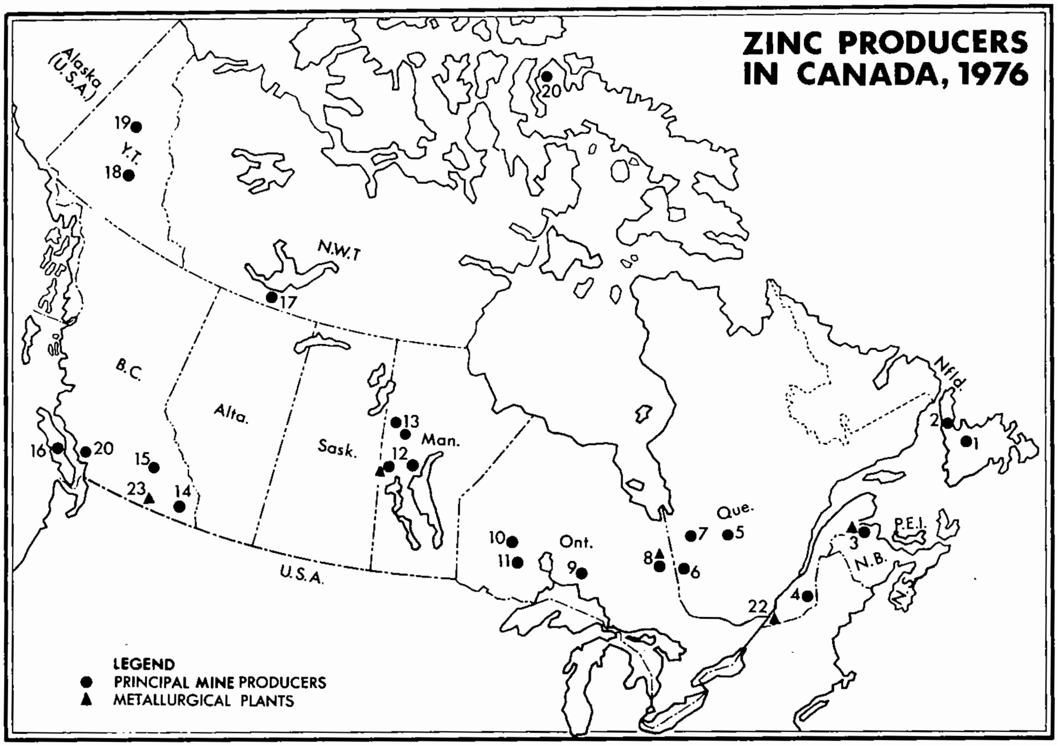
Metal production at Canadian Electrolytic Zinc Limited increased modestly to 114 100 tonnes in 1976 from 106 800 tonnes in 1975. Installation of plant and equipment to increase capacity from 380 tonnes a day to 560 tonnes a day was completed in April 1976; however, continued poor market conditions precluded production at the expanded capacity level during the year. As of January 1, 1976 ownership of the expanded plant was changed to: Mattagami Lake Mines Limited, 51.67 per cent; Noranda Mines Limited, 22.67 per cent; Orchan Mines Limited, 15.83 per cent and Kerr Addison Mines Limited, 9.83 per cent. Texasgulf Canada Ltd. increased metal production at its electrolytic zinc plant to 97 700 tonnes in 1976 from 84 400 tonnes in 1975. The electrolytic zinc plant at Trail owned by Cominco Ltd. produced 203 200 tonnes of refined zinc in 1976 compared with 176 000 tonnes in 1975. Cominco plans to replace the existing zinc plant at Trail with a 275 000-tonne-a-year electrolytic zinc plant that will use high productivity cells developed by the company. Construction of the new plant will commence in 1978. The Flin Flon, Manitoba electrolytic zinc plant owned by Hudson Bay Mining and Smelting Co., Limited produced 54 800 tonnes of refined zinc in 1976 compared with 59 100 tonnes in 1975.

A feasibility study for a 100 000 tonne-a-year electrolytic plant, conducted by Brunswick Mining and Smelting Corporation Limited, was completed at mid-year 1976. The preliminary capital cost estimate of the proposed plant in the Belledune, New Brunswick area, undertaken by an engineering consortium of Hatch & Associates, Montreal Engineering, Lurgi Canada Ltd., and Canadian Electrolytic Zinc, came to about $200 million as of the anticipated completion of construction in 1980. Company officials indicated that the financial resources available during 1977 and 1978 would not permit undertaking construction of the pro-

Table 10. Canada, producers' domestic shipments of refined zinc, 1974-76

	1974	1975	1976[p]
		(tonnes)	
1st Quarter	38 156	23 898	30 656
2nd Quarter	39 595	40 903	40 251
3rd Quarter	24 359	47 688	31 858
4th Quarter	32 311	36 725	30 796
Total	134 421	149 214	133 561

Source: Statistics Canada.
[p] Preliminary.



Principal Producers

(numbers refer to numbers on map)

1. ASARCO Incorporated (Buchans Unit)
2. Newfoundland Zinc Mines Limited
3. Brunswick Mining and Smelting Corporation Limited
   Heath Steele Mines Limited
   Nigadoo River Mines Limited
4. Sullivan Mining Group Ltd.
5. Lemoine Mines Ltd.
6. Falconbridge Copper Limited, Lake Dufault Division
   Manitou-Barvue Mines Limited
   Louvem Mining Company Inc.
7. Mattagami Lake Mines Limited
   Orchan Mines Limited
8. Texasgulf Canada Ltd.
9. Noranda Mines Limited (Geco Division)
   Willroy Mines Limited
10. Selco Mining Corporation Limited
11. Mattabi Mines Limited
    Falconbridge Copper Limited (Sturgeon Lake Joint Venture)
12. Hudson Bay Mining and Smelting Co., Limited (Chisel Lake, Osborne Lake, Stall Lake, Ghost Lake, Anderson Lake, Schist Lake, Flin Flon, White Lake, Centennial)
13. Sherritt Gordon Mines Limited (Fox Lake mine and Ruttan mine)
14. Cominco Ltd. (Sullivan mine and H.B. mine)
    Teck Corporation Limited (Beaverdell mine)
    Kam-Kotia Mines Ltd. (Silmonac mine)
15. Consolidated Columbia River Mines Ltd. (Ruth Vermont Mine)
16. Western Mines Limited
17. Pine Point Mines Limited
18. Cyprus Anvil Mining Corporation
19. United Keno Hill Mines Limited
20. Northair Mines Ltd.
21. Nanisivik Mines Ltd.

Metallurgical Plants

8. Texasgulf Canada Ltd., Hoyle
12. Hudson Bay Mining and Smelting Co., Limited, Flin Flon
22. Canadian Electrolytic Zinc Limited, Valleyfield
23. Cominco Ltd., Trail

posed plant during this period; however, despite the current financial constraints, it was noted that the orebody is one of the great zinc deposits in the world and that, at an appropriate time, it would merit a zinc plant. In October 1976 a Federal-Provincial Task Force was established to determine the economic viability of a zinc plant in northern New Brunswick.

Metal consumption in Canada

Canadian consumption of primary zinc is estimated to be 125 000 tonnes in 1976 compared with 120 000 tonnes in 1975. Typically, usage is broken down into: protective coatings, 49 per cent; alloy for diecast parts, 21 per cent; brass, 12 per cent; and a general category, including zinc oxide as the major component; 18 per cent. The Zinc Institute, Inc. reports that consumption increased in all market sectors in 1976 coincident with improved activity throughout the economy during the year.

During 1975 the Institute conducted a survey of the 59 Canadian diecasters to determine end usage of diecast parts, which indicated a market breakdown as follows: automotive components, 38.2 per cent, most of which are exported to the United States; builders' hardware, 28.3 per cent; electrical components, 11.4 per cent; industrial-agricultural-commercial machinery, 5.5 per cent; sound and television equipment, 1.3 per cent; sporting goods and toys, 0.8 per cent; scientific and professional equipment, 0.1 per cent and miscellaneous industries, 6.3 per cent. Automotive and electrical components and builders' hardware accounted for nearly 80 per cent of all diecast parts produced in Canada. The major diecasting companies were Hudson Bay Diecasting Limited, Doehler Canada Limited, Albright Platers Ltd. and National Hardware Specialties Limited. The protective coatings market, represented primarily by 41 galvanizing companies, includes the largest industrial consumers of zinc in Canada; The Steel Company of Canada, Limited and Dominion Foundries and Steel, Limited, which have continuous lines for the galvanizing of sheet steel. Of the 135 foundries in Canada that produced brass and other copper alloys, the four major companies that consumed zinc metal were Noranda Manufacturing Ltd., The Canada Metal Company, Limited, Anaconda Copper and Brass Co., and Radcliff (Canada) Ltd. The main producers of zinc oxide were Zochem Limited, Pigment and Chemical Company Limited, and G.H. Chemicals Ltd.

Characteristics and uses

The wide use of zinc stems from its chemical and metallurgical properties. Its major areas of application are in galvanizing, zinc-alloy castings, rolled zinc, brass-making, as the major additive to copper; and in zinc chemicals used in manufacturing rubber, paints and pharmaceuticals. In many instances the cost of zinc is not a significant factor in end-product production costs.

In certain applications, especially automotive, where competition with aluminum and plastics and reduced unit-consumption of zinc, e.g., thin-wall zinc diecasting, has occurred; zinc has lost ground. In the future, the weight factor may be an important constraint in zinc diecasting for the automotive industry.

The largest use of zinc is in galvanizing iron and steel products. It provides a corrosion-resistant coating which can be readily finished with electroplated metal coatings or organic coatings.

Galvanizing is done by batch or continous hot dip or electrolytic processes, with the main product categories being sheet and strip, tube and pipe, and wire and wire rope. The market for galvanized sheet and strip steel is of major importance, both in size and growth. These products are used primarily by the construction, automobile and building industries for roofing, siding, appliance casings, office equipment, decking to support concrete floors, heating and ventilation ducts, automobile door panels and underbody parts.

The ability to control zinc thicknesses on steel by electrolytic processes has resulted in new products such as prepainted galvanized steel clapboard siding for residential and industrial buildings. The introduction of single-sided galvanized sheet with improved weldability in auto body manufacture is expected to increase consumption in the sheet and strip line.

Aluminum is an alternative coating for sheet and strip steel; however, its usage is marginal at present because of higher costs, and its inability to provide sacrificial protection to substrate metal when scratched, as zinc does. The tube, pipe, wire and wire rope coatings markets have declined in recent years with the substitution of copper and plastic products for usages such as residential plumbing systems and plastic-coated residential fencing.

In Australia a new zinc-aluminum alloy coating known as *zincalume* which provides twice the longevity of zinc corrosion protection on sheet steel at about the same cost has been successfully introduced. The alloy consists of 55 per cent aluminum, 43.4 per cent zinc and 1.6 per cent silicon and is applied in a standard coating of 150-200 grams per square metre, compared with 300-430 grams per square metre for zinc. The new product is being used currently in sheet steel roofing and wall cladding applications and it may eventually capture the majority of the domestic market, estimated to be about 150 000 tonnes a year.

Overall substitution by alternative materials does not appear to pose a serious threat to the protective coating market for zinc; of greater concern is obsolescence through the possible development of low-cost corrosion-resistant steels.

Zinc diecast parts, the second largest use of zinc, are used as trim pieces, grills, door and window handles, carburetors, pumps, door locks and other mechanical components in automobiles. In the United States the automobile industry uses approximately two-thirds of total production of zinc diecastings. Diecastings are also used in small appliances, business equipment and light engineering industries.

Possible substitutes for zinc in diecasting are magnesium, aluminum and plastics, the latter as a result of the development of metal-on-plastic plating techniques. The most significant factor in North America affecting zinc diecast parts is the trend to produce smaller and lighter cars. Weight is an issue in the automotive industry and some industry officials forecast a decline in zinc diecast consumption per automobile from the level of about 40 pounds in 1976 to about 25 to 30 pounds by 1980. By comparison, the average consumption of aluminum per vehicle is expected to increase from 87 pounds in 1967 to 150-200 pounds in 1980. Likewise plastics are expected to increase from 160 pounds in 1976 to 300 pounds in 1980. At the same time, oil-based energy considerations may well provide a significant new market for nickel-zinc batteries associated with the development of electric vehicles during the next decade.

Increasing acceptance of thin-wall zinc diecast parts will preserve some automotive applications and possibly obtain others, but unit consumption per car will decline, although the decline will likely be partially offset by automobile production growth and increased usage in corrosion protection.

The manufacture of brass is the third major area of zinc consumption. Brass is used in a variety of applications from decorative hardware to plumbing and heat exchange units. It combines good physical, electrical,

Table 11. Western world zinc industry, production and consumption, 1976

	Mine Production	Metal Consumption	Metal Production	Metal Capacity[e]	Per cent Capacity Utilization
	(000 tonnes primary zinc)				
Europe (EEC-EFTA)[1]					
Austria	18.1	21.3	18.4	18	100.0
Belgium	—	122.5	234.8	333	70.5
Denmark	81.5	9.4	—	—	—
Finland	59.7	20.5	110.7	150	73.8
France	37.1	265.1	233.1	299	77.9
West Germany	135.2	331.3	303.6	434	69.9
Ireland	66.0	4.0	—	—	—
Italy	78.5	204.0	191.2	260	73.5
Netherlands	—	26.0	115.8	150	77.2
Norway	29.2	21.0	62.9	90	69.8
Portugal	—	9.0	—	—	—
Sweden	112.8	38.7	—	—	—
Switzerland	—	18.5	—	—	—
United Kingdom	—	240.4	41.5	90	46.1
Total	618.1	1 331.7	1 312.0	1 823	71.9
Europe (Other)					
Greece	27.5	13.0	—	—	—
Spain	81.4	114.3	161.1	165	97.6
Turkey	27.5	17.0	11.0	11	100.0
Yugoslavia	79.0	67.0	101.0	115	87.8
Total	215.4	211.3	273.1	291	93.8
Africa					
Algeria	18.0	—	27.0	40	67.5
Congo	4.0	—	—	—	—
Morocco	20.0	—	—	—	—
South Africa	122.6	59.7	66.2	85	77.8
Tunisia	11.0	—	—	—	—
Zaire	75.0	—	63.3	70	90.4
Zambia	50.0	—	39.5	64	61.7
Other	—	54.0	—	—	—
Total	300.6	113.7	196.0	259	75.6

Table 11. (concl'd)

	Mine Production	Metal Consumption	Metal Production	Metal Capacity[e]	Per cent Capacity Utilization
	(000 tonnes primary zinc)				
Americas					
Canada	1 145.0	125.0	472.3	636	74.2
United States	476.0	1 021.7	486.1	607	80.0
Mexico	240.0	60.0	161.5	197	81.9
Argentina	40.0	40.5	30.0	51	58.8
Brazil	48.0	106.0	39.0	48	81.2
Bolivia	60.0	—	—	—	—
Peru	385.0	10.0	67.5	73	92.4
Other	24.0	36.0	—	—	—
Total	2 418.0	1 399.2	1 256.4	1 612	77.9
Asia					
India	25.0	96.0	26.8	38	70.5
Burma	6.0	—	—	—	—
Japan	260.0	717.0	732.0	964	75.9
Other	62.0	108.0	—	—	—
South Korea	58.0	33.0	27.3	26	100.0
Total	411.0	954.0	786.1	1 029	76.3
Oceania					
Australia	414.4	83.1	246.0	315	78.0
New Zealand	—	18.0	—	—	—
Total	414.4	101.1	246.0	315	78.0
Total Western World	4 376.7	4 111.0	4 069.6	5 329	76.3

Sources: International Lead and Zinc Study Group; Statistics Canada.
[e] Estimated by the Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1] European Economic Community — European Free Trade Association.

thermal and corrosion-resistant qualities with an ability to be formed by a wide variety of processes. Brass is an alloy consisting essentially of zinc and copper with the amount of zinc ranging from 5 to 40 per cent. The low-to-medium zinc brasses are used for cold working, e.g., deep drawing and pressing, and the higher zinc brasses are used for hot working, e.g., extrusion, hot stamping, and casting. Additions of lead up to 3.7 per cent are made to higher zinc brasses when the product requires high-speed machining.

During periods of high copper and zinc prices a wide variety of other metals and plastics can substitute for brass.

Rolled zinc is used for dry battery production, photo engraving, lithographic printing plates, roof coverings and flashings, and rain water gutters and pipes. Roofing applications are generally confined to Europe where zinc has the tradition of being a building material. For these applications zinc is generally alloyed with a small quantity of copper and titanium.

Over one-half of the zinc oxide produced is used in the manufacture of rubber. Up to five per cent of the product weight consists of zinc oxide which is used as a catalyst in the vulcanization of natural and synthetic rubber. Zinc oxide is used as a white pigment in paint, and serves a variety of purposes in applications such as photocopy paper, agricultural products, cosmetics and medicinal products.

Zinc dust, which is a finely divided form of zinc metal, is used in the printing and dyeing of textiles, in zinc-rich paints, in purifying fats, and precipitating gold and silver from cyanide solutions. The more important industrial compounds of zinc are zinc sulphide, which in combination with barium sulphate forms the pigment lithopone; zinc sulphate, used in rayon fibre manufacture; and zinc chloride, a wood preservative.

Weather-resistant paints based on zinc oxide and zinc dust provide one of the most effective and durable protective coatings on outside surfaces, especially metallic ones. A new application is a two-coat paint system

Table 12. 1976 international zinc metal prices

Month	Canada	U.S.A.	Producers Outside N. America	L.M.E. Prompt
	¢/lb	¢/lb	$U.S./ tonne	£/tonne
January	37.0	37.1	795	340.9
February	37.0	37.0	795	340.4
March	37.0	37.0	795	374.0
April	37.0	37.0	795	427.7
May	37.0	37.0	795	427.6
June	37.0	37.0	795	424.4
July	37.0	37.0	795	434.2
August	37.8	38.8	795	415.0
September	39.0	39.5	795	412.1
October	37.6	38.1	795	389.8
November	36.3	37.0	795	368.2
December	36.6	37.0	795	382.3
1976 Average	37.2	37.5	795	394.7
1975 Average	37.0	38.9	366.6[1]	335.7

Source: International Lead Zinc Study Group Bulletin.
[1]Pound Sterling.

known as *Zincrometal* that can be hot-rolled on coiled steel. It is applied on a chromium-base coating. This system is reported to have corrosion resistance similar to galvanized steel, and could replace it in some applications. It has, however, important limitations, since tests show that it gives little if any sacrificial protection on scratched surfaces or cut edges. It is estimated that about 617 000 tonnes of Zincrometal was produced in the United States in 1976, with installed capacity capable of producing about 900 000 tonnes.

The International Lead Zinc Research Organization, Inc. (ILZRO) is the main body assisting industry to find new uses for lead and zinc. Promotion and advertising of new zinc products and processes is carried on by the Zinc Institute, Inc. which opened a branch office in Toronto in 1968. The development of thin-walled diecastings and improved zinc-based diecasting alloys has done much to expand the use of zinc as a diecasting metal in competition with alternative materials such as aluminum and plastics.

Prices

Zinc metal prices declined during 1976 in response to a surplus availability of metal worldwide. In some areas, published producer price quotations gave the appearance of greater stability than actually existed as the practice of unpublished discounts became firmly entrenched by the end of the year.

Outside North America the "GOB Producer basis" quotations for zinc published by *Metal Bulletin* in London, England, were converted from a pound sterling quotation to a U.S. dollar quotation of $795 a metric ton effective January 2, 1976 as a response by primary metal producers to the continued erosion of the pound sterling against other currencies. Delivery of "Good Ordinary Brand" (GOB) zinc metal is considered to be cif world port, which excludes import duty, grade premium, and inland freight to buyers' works. During 1976 traditional additional revenues to cover such costs for direct delivery to customers were eroded if not eliminated.

Furthermore, competition among producers for increased market shares, high levels of metal held by merchants, plus excessive shipments of metal (primarily North Korean) to the London Metal Exchange, combined to create a situation where price competition became widespread, particularly in Europe. During the course of 1976 this competition evolved from extended credit and guaranteed price protection in the weak £ sterling, to direct discounts from the posted price in line with declining cash quotations for zinc on the London Metal Exchange.

In North America, where 86 per cent of Canadian zinc production was marketed in 1976, zinc metal prices declined despite several attempts by producers to increase them during the year. On January 5, 1976 ASARCO Incorporated in the United States initiated a domestic price reduction, which for prime western grade zinc, reduced the price to 37 cents a pound. Increased imports were cited as the reason for the change. The 2-cent-a-pound decline was immediately adopted by all other domestic producers and it was applied to all grades of zinc metal. The Canadian metal producers, which sell to consumers in the United States on a delivered basis including duty, followed the move by the U.S. industry and reduced prices from 39 cents a pound to 37 cents a pound effective January 7 and 8; however, metal prices in Canada were left unchanged at the 37-cent-a-pound level. On August 3, 1976 Texasgulf Inc. initiated a 3-cent-a-pound price increase to all grades of zinc metal sold in the United States, and in a similar move on August 6, prices in Canada were increased by 1.5 cents a pound. Texasgulf's new price for prime western was therefore 40 cents a pound in the United States and 38.5 cents a pound in Canada, but the reaction of other producers to this move was slow and mixed. In the United States a split price developed as some producers only increased prices by 2 cents a pound. On August 27 the other Canadian producers raised their United States prices by 3 cents a pound but increased domestic prices in Canada by 2 cents a pound, and immediately Texasgulf Inc. brought its Canadian prices into line with other producers at the 39-cent-a-pound level for prime western zinc. During this period of time much

(text continued on page 635)

Table 13. Canadian and United States producers' zinc metal prices (delivered) in 1976

	Date(s) Effective	Prime Western	High Grade	Special High Grade	Continuous Line Pb Control	Continuous Line Al Added
		(Cdn. ¢ a pound)				
Canada						
All Producers[1]	Prior to Aug. 6	37.0	37.0	37.5	37.25	37.5
Texasgulf Inc.	Aug. 6	38.5	38.5	39.0	38.75	39.0
All Producers	Aug. 26 & 27	39.0	39.0	39.5	39.25	39.5
All Producers	Oct. 14 & 15	36.25	36.25	36.75	36.5	36.75
Noranda Sales Corp. Ltd.	Dec. 14 (Rescinded Jan. 3, 1977)	37.75	37.75	38.25	38.0	38.25
		(U.S. ¢ a pound)				
United States						
All Producers	Prior to Jan. 7	39.0	39.0	39.5	39.25	39.25
All Producers	Jan. 7 & 8	37.0	37.0	37.5	37.25	37.5
Texasgulf Inc.	Aug. 3	40.0	40.0	40.5	40.25	40.5
All Producers	Aug. 17	40.0	40.0	40.5	40.25	40.5
All Producers	Oct. 14 & 15	37.0	37.0	37.5	37.25	37.5

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Includes Cominco Ltd., Hudson Bay Mining & Smelting Co. Ltd., Texasgulf Inc., and Noranda Sales Corporation Ltd.

Table 14. Free world, zinc supply-demand balance 1973-1985

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
					(000 tonnes zinc content)						
Free world mine production	4 403	4 391	4 810	4 903	5 082	5 120	5 217	5 312	5 395	5 652	5 905
less: Exports to Socialist countries	120	100	100	100	100	125	125	125	150	150	150
Ores reduced directly to chemical compound	50	59	57	55	50	50	50	50	50	50	50
Processing losses net of secondary supplies	227	198	226	242	249	250	256	261	264	280	295
Metal equivalent of mine production	4 006	4 034	4 427	4 546	4 683	4 695	4 786	4 876	4 931	5 172	5 410
Free world metal production	3 759	4 070	4 200	4 300	4 650	4 800	4 940	5 100	4 931	5 172	5 410
Mine balance: surplus (deficit)	247	(36)	227	246	33	(105)	(154)	(224)	(–)	(–)	(–)
Free world metal consumption	3 530	4 111	4 350	4 480	4 615	4 753	4 896	5 043	5 194	5 350	5 510
less: Imports from Socialist countries	82	89	76	50	50	50	50	50	50	50	50
plus: National stockpile purchases[1]	2	12	–	50	88	100	93	100	100	100	100
Net metal demand	3 450	4 034	4 274	4 480	4 653	4 803	4 939	5 093	5 244	5 400	5 560
Free world metal production	3 759	4 070	4 200	4 300	4 650	4 800	4 940	5 100	4 931	5 172	5 410
Metal balance: surplus (deficit)	309	41	(74)	(180)	(3)	(3)	1	7	(313)	(328)	(150)
Total balance: surplus (deficit)	556	5	153	66	30	(108)	(153)	(217)	(313)	(328)	(150)
Metal capacity	5 180	5 329	5 548	5 647	5 767	5 927	6 250	6 413	6 413	6 473	6 547
Per cent utilization of metal capacity	73	76	76	76	81	81	79	80	77	80	84

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]United States, France, Japan.
– Nil.

Table 15. Forecast of capacities of non-communist world zinc plants, 1974-85

	Primary Zinc Plant		Estimated Capacity			Expected Capacity					
Company	Location	Type[1]	1974	1975	1976	1977	1978	1979	1980	1981	1982-85
			(000 tonnes)								
America											
United States											
AMAX	Sauget, Ill.	E	73	73	73	73	73	73	73	73	73
ASARCO	Amarillo, Tex.	HR	50	21	—	—	—	—	—	—	—
ASARCO	Corpus Christi, Tex.	E	95	95	95	115	115	115	115	115	115
ASARCO	Stephensport, Kty.[2]	E	—	—	—	—	—	—	—	—	163
Bunker Hill	Kellogg, Ida.	E	99	99	99	99	99	99	99	99	99
National Zinc	Bartlesville, Okla.	HR (E1976)	41	41	50	52	52	52	52	52	52
New Jersey Zinc	Palmerton, Pa.	VR	80	80	80	80	80	80	80	80	80
Jersey Miniere Zinc	Clarksville, Tenn.[3]	E	—	—	—	—	—	40	80	80	80
St. Joe Minerals	Monaca, Pa.[4]	ET	200	200	200	200	200	200	200	200	200
			638	628	607	619	619	659	699	699	862
Canada											
Cominco	Trail, B.C.	E	244	250	250	250	250	250	250	275	275
Hudson Bay M. & S.	Flin Flon, Man.	E	73	73	73	73	73	73	73	73	73
C.E. Zinc	Valleyfield, Que.	E	132	132	205	205	205	205	205	205	205
Texasgulf	Timmins, Ont.	E	108	108	108	108	108	108	108	108	108
Brunswick M. & S.	Belledune, N.B.[5]	E	—	—	—	—	—	—	—	100	100
			557	563	636	636	636	636	636	761	761
Mexico											
Ind. Minera Mexico	Rosita[6]	HR	62	62	62	62	62	62	62	—	—
Ind. Minera Mexico	San Luis Potosi	E	—	—	—	—	—	—	—	110	110
Zincamex	Saltillo	HR	30	30	30	30	30	30	30	30	30
Ind. Penoles	Torreon	E	65	105	105	105	105	105	105	105	105
			157	197	197	197	197	197	197	245	245
Argentina											
Sulfacid	Borghi	E	26	26	26	26	26	26	26	26	26
Cia Metalurgica Austral	Comodoro	ET	16	16	16	16	16	16	16	16	16
Meteor	Zarate	E	9	9	9	9	9	9	9	9	9
			51	51	51	51	51	51	51	51	51

Brazil											
Cia Ind. E. Mercantil Inga	Itaguai	E	10	10	10	10	10	10	10	10	10
Cia Mineira De Metais	Tres Marias	E	25	25	38	45	50	50	50	50	50
Paraibuna De Metais	Juiz De Fora	E	—	—	—	—	—	15	30	30	30
			35	35	48	60	60	75	90	90	90
Peru											
Centromin	La Oroya	E	73	73	73	73	80	85	90	90	90
Minero Peru	Cajamarquilla	E	—	—	—	—	—	—	50	100	100
			73	73	73	73	80	85	140	190	190
Total, America			1 511	1 547	1 612	1 636	1 643	1 703	1 813	2 036	2 199
EEC, Europe											
Belgium											
Hoboken Overpelt	Overpelt	VR (E1975)	88	100	100	100	100	100	100	100	100
Vieille Montagne S.A.	Balen	E	168	168	168	168	168	168	168	168	168
Soc. Prayon	Ehein	E	65	65	65	65	65	65	65	65	65
			321	333	333	333	333	333	333	333	333
France											
Vieille Montagne S.A.	Viviez	E	94	94	94	94	94	94	94	94	94
Vieille Montagne S.A.	Creil	HR	9	—	—	—	—	—	—	—	—
Penarroya S.A.	Noyelles Godault	ISP	105	105	105	105	130	135	135	135	135
Cie Royale Asturienne	Auby	VR (E1975)	90	95	100	100	100	100	100	100	100
			298	294	299	299	324	329	329	329	329
West Germany											
Duisburger Kupferhutte	Duisburg	E	10	10	10	10	10	10	10	10	10
Metall. (Berzelius)	Duisburg	ISP	80	80	80	80	80	90	95	95	95
Metall. (Ruhr Zinc)	Datteln	E	130	130	130	130	130	130	130	130	130
Preussag	Harlingerode	VR	94	94	94	94	94	94	94	94	94
Preussag Weser Zinc	Nordenham	E	120	120	120	120	120	120	120	120	120
			434	434	434	434	434	444	449	449	449
Italy											
Soc. Pertusola	Crotone	E	90	90	90	90	100	110	120	130	130
Ammi	Bergano	E	35	35	35	35	35	35	35	35	35
Ammi	Monteponi	E	15	15	15	15	15	15	15	15	15
Ammi	Porto Marghera	E	45	45	45	45	45	45	45	45	45
Ammi Sarda	Porto Vesme	ISP	50	50	75	75	75	75	75	75	75
			235	235	260	260	270	280	290	300	300

Table 15. (cont'd)

Company	Primary Zinc Plant		Estimated Capacity			Expected Capacity					
	Location	Type[1]	1974	1975	1976	1977	1978	1979	1980	1981	1982-85
			(000 tonnes)								
Netherlands											
Kemp. Zinc de la Campine	Budel	E	20	—	—	—	—	—	—	—	—
Budelco	Budel	E	120	150	150	170	170	170	170	170	170
			140	150	150	170	170	170	170	170	170
United Kingdom											
Commonwealth Smelting	Avonmouth	ISP	90	90	90	90	90	90	90	90	90
Total, EEC, Europe			1 518	1 536	1 566	1 586	1 621	1 646	1 661	1 671	1 671
Others, Europe											
Austria											
Bleiberger Bergwerks	Gailitz	E	17	17	18	22	24	24	24	24	24
Finland											
Outokumpu Oy	Kokkola	E	90	150	150	150	150	150	150	150	150
Norway											
Norzink	Eitrheim	E	85	85	90	90	100	105	105	105	105
Spain											
Asturiana Ɗe Zinc	Aviles	E	105	110	135	200	200	200	200	200	200
Espanol Del Zinc	Cartagena	E	30	30	30	60	60	60	80	80	80
			135	140	165	260	260	260	280	280	280
Turkey											
Cinko-Kursan	Incesu	E	—	—	11	30	40	40	40	40	40
Yugoslavia											
Hemijska Ind. Zorka	Sabac	E	25	25	25	25	30	35	40	40	40
R.M.H.K. Trepca	Zvencan	E	35	35	35	35	35	35	55	80	80
Top.Za.Cink 1.Zletovo	Titov Veles	ISP	50	55	55	55	55	55	55	55	55
			110	115	115	115	120	125	140	175	175
Total, others, Europe			437	505	547	677	694	704	739	769	769
Total, Europe			1 955	2 041	2 115	2 263	2 315	2 350	2 400	2 440	2 440

Africa											
Algeria											
Soc. Nat. de Siderurgie	Ghazaouet	E	—	30	40	40	40	40	40	40	40
South Africa											
Zinc Corporation	Vogelstuisbuilt	E	65	85	85	85	85	85	85	85	85
Zaire											
Soc. Met. Katangese	Kolwezi	E	70	70	70	70	70	70	70	70	70
Zambia											
Nchanga Cons. Copper	Broken Hill	ISP	34	34	34	34	34	34	34	34	34
Nchanga Cons. Copper	Kabwe	E	30	30	30	30	30	30	30	30	30
			64	64	64	64	64	64	64	64	64
Total, Africa			199	249	259	259	259	259	259	259	259
Oceania											
Australia											
Electrolytic Zinc	Risdon	E	200	200	200	200	200	200	200	200	200
Sulphide Corp.	Corkle Creek	ISP	70	70	70	70	70	70	70	70	70
Broken Hill Assoc. Smelters	Port Pirie	E	45	45	45	45	45	45	45	45	105
Total, Oceania			315	315	315	315	315	315	315	315	375
Asia											
India											
Hindustan Zinc	Debari	E	18	18	18	45	45	45	45	45	45
Hindustan Zinc	Vishakhpatnam	E	—	—	—	20	30	30	30	30	30
Cominco-Binani	Kerala	E	20	20	20	20	20	20	20	20	20
			38	38	38	85	95	95	95	95	95
Japan											
Akita Co.	Iijima	E	90	156	156	156	156	156	156	156	156
Hachinohe S. Co.	Hachinohe	ISP	76	76	76	76	76	76	76	76	150
Mitsubishi M. Corp.	Akita	E	97	97	97	97	97	97	97	97	97
Mitsubishi M. Corp.	Hosokura	E	20	20	20	20	20	20	20	20	20
Mitsui M. & S.	Hikoshima	E	66	66	66	66	66	66	66	66	66
Mitsui M. & S.	Kamioka	E	61	61	61	61	61	61	61	61	61
Mitsui M. & S.	Miike	E	20	20	20	20	20	20	20	20	20
Mitsui M. & S.	Miike	VR	118	118	118	118	118	118	118	118	118
Nippon M. Co.	Mikkaichi	ET	120	120	120	120	120	120	120	120	120
Nisso S. Co.	Aizu[7]	E	31	31	31	31	31	31	31	31	31
Sumiko ISP Co.	Harima	ISP	60	60	60	60	60	60	60	60	60
Toho Zinc Co.	Annaka	E	139	139	139	139	143	143	143	143	143
			898	964	964	964	969	969	969	989	1 043

Table 15. (concl'd)

Company	Primary Zinc Plant Location	Type[1]	Estimated Capacity 1974	1975	1976	Expected Capacity 1977	1978	1979	1980	1981	1982-85
			(000 tonnes)								
Asia (cont'd.)											
Thailand											
Thai Zinc	Tak	E	–	–	–	–	–	–	–	60	60
Republic of Korea											
Korea Zinc Co.	Onsan	E	–	–	–	–	25	50	50	50	50
Tong Shin Chemical	Seoul	E	6	6	6	6	6	6	6	6	6
Eiho Shoji Co.	Sekiho	E	9	20	20	20	20	20	20	20	20
			15	26	26	26	51	76	76	76	76
Total, Asia			951	1 028	1 028	1 075	1 115	1 140	1 140	1 200	1 274
Total, noncommunist world			4 931	5 180	5 329	5 548	5 647	5 767	5 927	6 250	6 547

Source: Mineral Development Sector, Department of Energy, Mines and Resources, Ottawa.
[1]Type of zinc plant is abbreviated as follows: E, Electrolytic; HR, Horizontal Retort; ISP, Imperial Smelting Process; VR, Vertical Retort; ET, Electrothermic. [2]Anticipated construction of agreed joint venture with M-I-M Holdings Limited. [3]Announced joint venture with Union Minière S.A. [4]Total slab capacity 285 000 tonnes, including 40 000 tonnes expansion in 1973-76. However, 85 000 tonnes devoted to oxide production. [5]Anticipated construction of integrated refinery currently in feasibility stage. [6]Anticipated closure associated with new 110 000-tonne plant at San Luis, Potosi, commencing 1981. [7]Converted to processing secondary feed in 1977.
– Nil.

confusion was evident in the marketplace. The combination of discounts arising from the split price, price protection at the previous price, and low-priced imports, virtually eliminated demand for metal at the posted 40-cent-a-pound level for prime western. During the period October 12 to 14, 1976 all U.S. producers rescinded their price increases, with the reductions made retroactive to August when they were first introduced. The Canadian producers followed this initiative and reduced prices in the United States to the original 37-cents-a-pound level on October 14, 1976. At the same time, prices in Canada were reduced by 2.75 cents a pound for all grades of zinc, leaving the price of prime western at 36.25 cents a pound compared to 37 cents a pound prior to August. On December 14, 1976 Noranda Sales Corporation Ltd. raised domestic prices in Canada by 1.5 cents a pound; however, other producers did not follow and the increase was rescinded January 3, 1977. These price changes are shown in Table 13 and illustrated on the chart entitled "Zinc Prices-Monthly Averages". Zinc metal quotations on the London Metal Exchange (LME) in England remained at a discount to posted producer price levels throughout the year and on a monthly-average basis attained a low of 27.4 cents a pound in November 1976, representing a spread of 8.7 cents a pound from the posted producer price on the continent. It is generally accepted knowledge that the LME, as a source of metal, represents about 5 per cent of western world consumption. Delivery of LME metal (min. 98 per cent purity) is taken at the LME warehouses in the United Kingdom and on the continent.

Western World mine production

Mine production of zinc in 1976 was 4 376 700 tonnes compared with 4 403 200 tonnes in 1975. During the year 282 000 tonnes of new mine capacity came into production, offset by 9 000 tonnes in closures; however, there was little evidence of the expanded mine capacity as continued poor metal markets kept production well below capacity, with some mines adjusting output to the demand for concentrate.

During the period 1977-81 a further 1 029 000 tonnes of new zinc mine capacity has been announced to come on stream but it is expected that some proportion of these new projects will be deferred due to continued poor metal markets and a reduced ability by the industry at large to undertake new investment following the third consecutive year of declining profitability. Such developments could prove to be unfortunate because, as illustrated in Table 14, expectations for the various components affecting supply and demand in the zinc industry could result in a greater demand for zinc metal than would be available from the mine sector during the 1980-85 period. In compiling this forecast new mine production was assumed to operate at 85 per cent of capacity, and an allowance of 2.2 per cent per annum was made for declining production from existing mines.

Western World metal production

Primary zinc metal production in the western world amounted to 4 070 000 tonnes in 1976 compared with 3 759 000 tonnes in 1975. Available refined metal capacity stood at 5 329 000 tonnes at year-end 1976, thereby leaving 1 259 000 tonnes of surplus capacity idle during the year. Overall, the refining industry operated at a 76 per cent utilization rate during the year compared with 73 per cent in 1975; however the burden of constraint was not shared equally, as is shown in Table 11. Capacity is forecast to remain surplus to net metal demand by about one million tonnes to at least 1980, and possibly to 1985. On this basis, refineries around the world are expected to operate at or below 80 per cent of capacity until at least 1981, as shown in Tables 14 and 15.

Western World metal consumption

Primary zinc metal consumption in the Western World increased to 4 111 000 tonnes in 1976 from 3 529 500 tonnes in 1975, but still remained below levels achieved in the period 1972 to 74. Expectations for 1977 are for a further increase to about 4 350 000 tonnes. Many industry and government observers now anticipate a lower growth rate of about 3 per cent a year in the coming decade compared to historical levels of about 4 per cent a year. The growth in consumption in Table 14 is premised upon the lower expectations commencing from a base level of 4 350 000 for 1977.

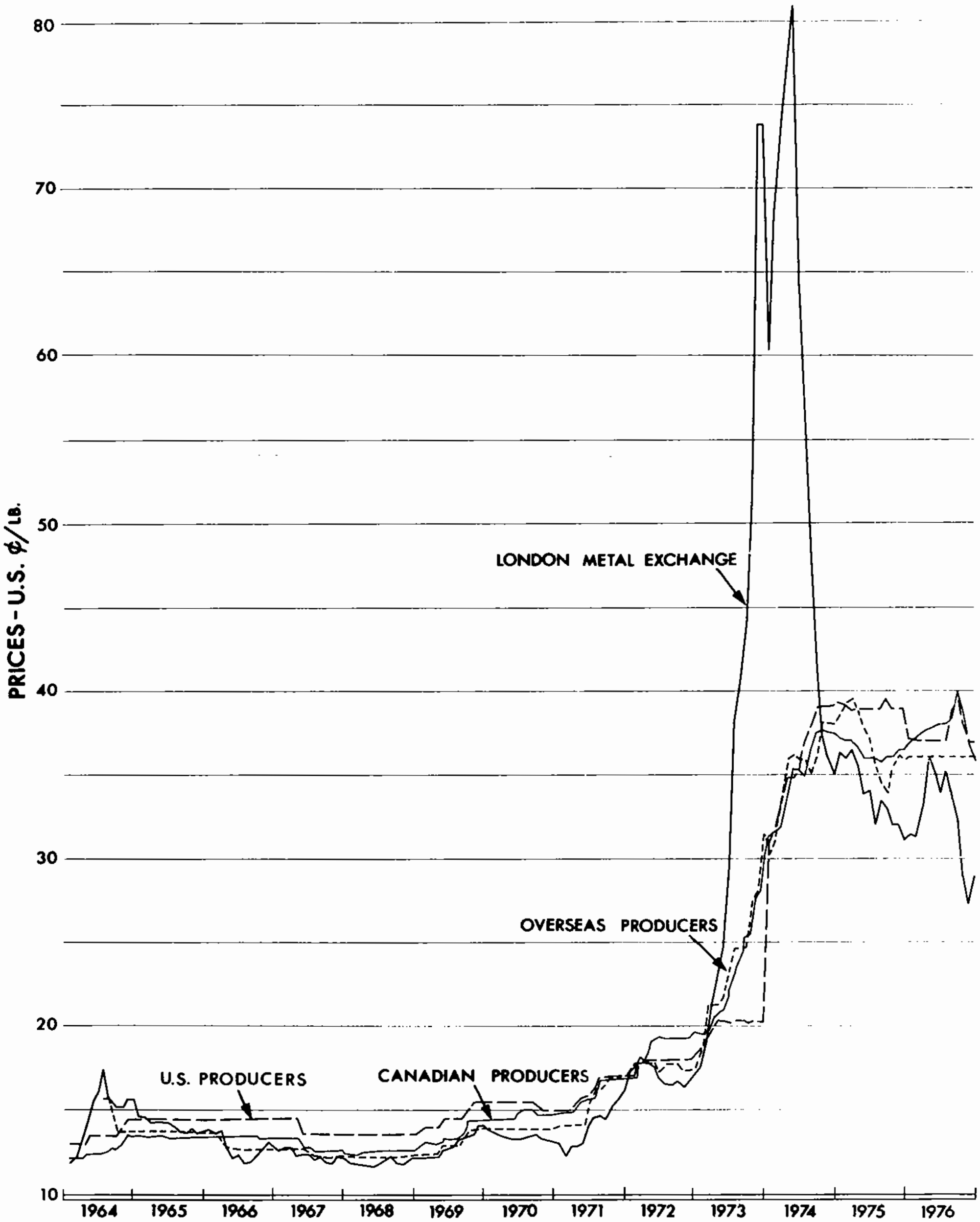
Western World outlook

Surplus metal, depressed operating volume and widespread price discounting practices which characterized the world industry in 1976 are expected to continue throughout 1977. The impact of a forecast 6 per cent volume improvement in metal demand for 1977 should be offset by an equal expansion in new refining capacity during the year. In addition a surge in new mine capacity in 1977 and 1978 is expected to generate a surplus of concentrate available to smelters in both years.

In contrast to refinery capacity, which is expected to remain very much surplus to demand until at least 1981 and possibly beyond, mine production could be in balance with metal demand by 1979 and could be in a deficit position thereafter. Some mine producers may be forced to reduce output as inventories are built up during 1977-78. Concomitantly, terms of sale for concentrate may deteriorate for spot contracts, whereas longer-term contracts may encounter some improvement compared to the 1975-76 levels. Due to the long lead times associated with new mine development, there appears to be a need for increased exploration expenditures but this may not fully materialize because of the difficulty in committing discretionary cash outflows when the industry is severely depressed financially.

Among metal producers, custom smelters are likely to be the most severely affected by a surplus of metal capacity and a tightening of mine supply. The financial impact of market conditions upon their operations should create strong pressures for higher prices in the period 1980 and beyond.

ZINC PRICES – MONTHLY AVERAGES



Tariffs

The following tariffs apply for zinc in its various forms

Canada

Item Number		GSP[1]	British Preferential	GATT[2]	General
32900-1	Zinc in ores and concentrates	Free	Free	Free	Free
34505-1	Zinc spelter, zinc and zinc alloys containing not more than 10% by weight of other metal or metals, in the form of pigs, slabs, blocks, dust or granules	Free	Free	Free	2¢/lb
34500-1	Zinc dross and zinc scrap for remelting, or for processing into zinc dust	Free	Free	Free	10%
35800-1	Zinc anodes	Free	Free	Free	10%

United States

USTS Number		GSP	GATT
602.20	Zinc ores and concentrates, on zinc content	0.67¢/lb[3]	0.67¢/lb[3]
	Unwrought zinc		
626.02	Unalloyed	0.7¢/lb	0.7¢/lb
626.04	Alloys of zinc	19%	19%
626.10	Zinc waste and scrap	0.75¢/lb[3]	0.75¢/lb[3]

European Economic Community

Brussels Tariff Nomenclature (BTN) Number		GSP	GATT
26.01	Zinc ore and concentrates	Free	Free
79.01	Unwrought zinc	3.5%	3.5%
	Zinc waste and scrap	Free	Free

Japan

Brussels Tariff Nomenclature (BTN) Number		GSP	GATT
26.01	Zinc ores and concentrates	Free	Free
79.01	Unwrought zinc, 97% zinc	12 Yen/kg[4]	12 Yen/kg[4]
	Zinc waste and scrap	Free	2.5%[5]

Sources: The Customs Tariff and Amendments, Department of National Revenue, Customs and Excise Division, Ottawa; Tariff Schedules of the United States Annotated (TSUS); Official Journal of the European Communities, Common Customs Tariff; Customs Tariff Schedules of Japan.

[1]GSP — Generalized System of Preferences extended to all, or most, developing countries. [2]GATT — General Agreement on Tariffs and Trade (most favoured nation treatment). [3]Duty temporarily suspended. [4]Temporarily reduced to 8 Yen/kg. [5]Temporarily reduced to 2%.

Statistical Summary

This chapter of the Yearbook is a statistical summary of Canadian mining and related activities. The statistical information is as comprehensive as possible, given the availability of data. Beginning with this issue of the Yearbook, the statistical information is in metric (SI) units. Historical series have been converted using the factors presented in the *Canadian Metric Practice Guide (Can 3-7234.1-76)*, prepared by the Canadian Standards Association.

The summary is divided into nine sections, each containing a number of statistical tables. The sections are preceded by a list of tables by section, number and title and by a table, "Canada, general economic indicators, 1962-76."

The sources of Canadian Mineral Industry statistics are Statistics Canada, other federal departments and agencies, provincial governments and company annual reports. International mineral statistics are derived from U.S. Bureau of Mines publications, *American Bureau of Metal Statistics, World Bureau of Metal Statistics, Metals Week, Engineering and Mining Journal,* the United Nations and the Organization for Economic Cooperation and Development.

Where applicable, an explanation of a concept or a term is contained in the footnote to a statistical table. If further information is required, the source of the information should be consulted.

The statistical summary was prepared by J.T. Brennan and Staff, Statistics Section, Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

STATISTICAL TABLES

SECTION 6, EMPLOYMENT, SALARIES AND WAGES

SECTION 7, MINING, EXPLORATION AND DRILLING

SECTION 8, TRANSPORTATION

SECTION 9, INVESTMENT AND FINANCE

		1962	1963	1964	1965	1966
Gross national product, current dollars	$ millions	42 927	45 978	50 280	55 364	61 828
Gross national product, constant dollars (1971=100)	"	58 475	61 487	65 610	69 981	74 844
Value of manufacturing industry shipments	"	26 713	28 741	31 560	33 889	37 303
Value of mineral production	"	2 881	3 027	3 365	3 715	3 981
Merchandise exports	"	6 179	6 799	8 094	8 525	10 071
Merchandise imports	"	6 258	6 558	7 488	8 633	10 072
Balance of payments, current account	"	-830	-521	-424	-1 130	-1 162
Corporation profits before taxes	"	4 450	4 932	5 841	6 318	6 714
Capital investment, current dollars	"	8 769	9 398	10 980	12 935	15 088
Capital investment, constant dollars (1971=100)	"	12 159	12 653	14 259	15 944	17 645
Population	000's	18 583	18 931	19 290	19 644	20 015
Labour force	"	6 615	6 748	6 933	7 141	7 420
Employed	"	6 225	6 375	6 609	6 862	7 152
Unemployed	"	390	374	324	280	267
Unemployment rate	%	5.9	5.5	4.7	3.9	3.6
Employment index	1961=100	102.2	104.3	108.2	114.3	120.7
Labour income	$ millions	21 816	23 262	25 367	28 201	31 878
Index industrial production	1971=100	58.8	62.5	68.7	74.4	79.3
Index manufacturing production	"	60.0	64.0	70.1	76.4	81.8
Index mining production	"	58.1	61.3	68.9	72.1	73.4
Index real domestic product	"	61.1	64.4	68.8	73.7	78.9
General wholesale price index	1935-39=100	240.0	244.6	245.4	250.3	259.5
Consumer price index	1971=100	75.9	77.2	78.6	80.5	83.5

[p] Preliminary; [r] Revised.

indicators, 1962-76

1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]
66 409	72 586	79 815	85 685	94 450[r]	105 234[r]	123 560[r]	147 175[r]	165 445	190 027
77 344	81 864	86 225	88 390	94 450[r]	100 248[r]	107 812[r]	111 766[r]	112 955	118 484
38 955	41 997	45 110	45 991	50 274	56 246	66 758	82 454[r]	88 457	98 597
4 381	4 722	4 734	5 722	5 963	6 408	8 370	11 751	13 347	15 393
11 112	13 270	14 498	16 401	17 397	19 671	24 838	31 739[r]	32 504	37 329
10 873	12 358	14 130	13 952	15 617	18 669	23 325	31 880[r]	34 805	37 469
-499	-97	-917	+1 106	+431	-386	+108[r]	-1 513[r]	-4 779	-4 187
6 823	7 742	8 294	7 699	8 681	10 799	15 032	18 800	20 159	20 102
15 348	15 455	16 927	17 798	20 184	22 218	26 618	32 882	38 216	42 072
17 571	17 628	18 498	18 635	20 184	21 255	23 519	24 752	25 233	25 480
20 378	20 701	21 001	21 297	21 569	21 821	22 095	22 446	22 800	23 110
7 694	7 919	8 162	8 396	8 643	8 918	9 321	9 704	10 060	10 308
7 379	7 537	7 780	7 919	8 107	8 363	8 802	9 185	9 363	9 572
315	382	382	476	536	555	519	519	697	736
4.1	4.8	4.7	5.7	6.2	6.2	5.6	5.3	6.9	7.1
122.6	122.7	127.0	127.1	127.8	129.9	135.9	142.8	141.1	144.1
35 303	38 444	43 065	46 706	51 528	57 570	66 358	78 520	93 562	107 612
81.9	87.9	93.7	95.2	100.0	107.2	116.8	120.5	114.8	120.5
83.8	90.0	96.5	95.2	100.0	106.9	116.1	120.1	114.2	120.0
77.7	83.3	83.9	95.8	100.0	106.5	118.9	118.3	109.3	110.4
81.4	87.1	92.3	94.6	100.0	105.5	113.0	117.6	118.7	124.2
264.1	269.9	282.4	286.4	289.9	310.3	376.9	461.3	491.6	512.4
86.5	90.0	94.1	97.2	100.0	104.8	112.7	125.0	138.5	148.9

Table 1. Mineral production of Canada, 1975 and 1976 and average 1972-76

	Unit of Measure	1975 (Quantity)	1975 ($000)	1976[p] (Quantity)	1976[p] ($000)	Average 1972-76 (Quantity)	Average 1972-76 ($000)
Metals							
Antimony	t	. .	7 369	. .	7 270	. .	5 062
Bismuth	t	157	2 647	154	2 491	116	1 668
Cadmium	t	1 192	8 967	1 292	7 462	1 513	10 677
Calcium	t	428	1 005	558	1 521	394	854
Cobalt	t	1 354	12 548	1 373	11 769	1 465	10 330
Columbium (Cb_2O_5)	t	1 662	6 854	1 656	6 935	1 686	5 714
Copper	000 t	734	1 030 503	747	1 126 156	769	1 104 633
Gold	kg	51 433	270 830	52 444	207 796	56 426	210 508
Indium	kg	6 967	. .	. .	. .	. .	. .
Iron Ore	000 t	44 893	918 065	56 902	1 241 263	46 963	795 721
Iron remelt	000 t	. .	80 753	. .	65 086	. .	61 528
Lead	000 t	349	155 973	259	129 388	316	131 071
Magnesium	t	3 826	8 788	5 858	12 248	5 444	8 063
Mercury	t	414	. .	—	—	366	. .
Molybdenum	Kg.	13 027	71 201	14 416	91 873	13 619	64 154
Nickel	000 t	242	1 100 523	262	1 232 143	251	967 569
Platinum group	kg	12 417	56 493	13 375	48 790	12 281	48 546
Selenium	t	182	7 362	260	9 134	243	7 179
Silver	kg	1 234 642	178 864	1 271 732	175 128	1 341 629	149 383
Tantalum (Ta_2O_5)	t	. .	. .	. .	. .	. .	. .
Tellurium	t	20	414	24	529	33	557
Thorium	t	—	—	—	—	—	—
Tin	t	319	2 366	275	1 873	242	1 570
Tungsten (WO_3)	t	1 478	. .	. .	. .	. .	. .
Uranium (U_3O_8)	t	5 517	. .	6 058	. .	4 934	. .
Zinc	000 t	1 055	872 328	1 040	862 296	1 117	746 497
Total metals			4 793 853		5 241 151		4 331 284
Nonmetals							
Arsenious oxide	t	—	—	—	—	—	—
Asbestos	000 t	1 056	267 246	1 549	445 523	1 494	291 039
Barite	000 t	81	2 306	100	1 860	84	1 400
Feldspar	000 t	—	—	—	—	2	46
Fluorspar	000 $	—	—	. .	2 246	. .	3 883
Gemstones	t	110	414	. .	414	. .	292
Gypsum	000 t	5 719	20 304	5 663	22 906	6 713	21 210
Magnesitic dolomite and brucite	000 t	. .	5 358	. .	5 116	. .	4 083
Nepheline syenite	000 t	468	8 869	541	10 828	518	8 528
Peat Moss	000 t	361	22 273	363	22 500	351	18 814
Potash (K_2O)	000 t	4 673	358 570	5 126	361 442	4 705	268 265
Pyrite, pyrrhotite	000 t	21	127	31	240	48	269
Quartz	000 t	2 492	13 112	2 376	23 895	2 460	11 956
Salt	000 t	5 123	59 714	5 752	75 691	5 257	57 160
Soapstone, talc & pyrophyllite	000 t	66	1 538	65	1 774	73	1 693
Sodium sulphate	000 t	472	22 049	490	24 878	510	15 113
Sulphur in smelter gas	000 t	695	9 641	781	15 454	688	10 019
Sulphur elemental	000 t	4 079	91 847	3 781	63 339	4 072	53 429
Titanium dioxide	000 t	. .	55 812	. .	74 410	. .	53 920
Total nonmetals			939 180		1 142 516		821 119

Table 1. (concl'd)

	Unit of Measure	1975 (Quantity)	1975 ($000)	1976^p (Quantity)	1976^p ($000)	Average 1972-76 (Quantity)	Average 1972-76 ($000)
Fuels							
Coal	000 t	25 259	586 423	25 311	604 000	22 236	364 716
Natural gas	000 m^3	87 485 758	1 520 661	86 858 171	2 466 621	86 283 713	1 112 017
Natural gas by-products	000 m^3	17 835	782 337	16 543	794 325	17 628	566 006
Petroleum crude	000 m^3	83 001	3 763 934	77 843	4 128 458	90 441	3 045 896
Total fuels			6 653 355		7 993 404		5 088 635
Structural materials							
Clay products	000 $	. .	85 977	. .	92 110	. .	71 773
Cement	000 t	9 965	320 172	9 850	339 159	9 946	278 784
Lime	000 t	1 602	46 907	1 825	54 099	1 752	40 631
Sand and Gravel	000 t	247 155	305 181	247 660	320 800	230 039	256 301
Stone	000 t	88 921	202 099	87 180	209 600	85 081	164 185
Total structural materials			960 336		1 015 768		811 674
Total all minerals			13 346 724		15 392 839		11 052 712

Note:
1. Production statistics for the following are not available for publication: diatomite, helium, mica, nitrogen, tantalum and yttrium.
2. Nil production for the following between 1972 and 1976: arsenious oxide, grindstone, iron oxide, lithia and thorium.
3. Dollar values only available for publication for the following: antimony, iron remelt, fluorspar, magnesitic dolomite and brucite, titanium dioxide and clay products.
4. Quantities only available for publication for the following: indium, mercury, tungsten and uranium.

^{p}Preliminary; . . Not available; — Nil.

Table 2. Canada, value of mineral production, per capita value of mineral production and population, 1936-76

	Metallics	Industrial Minerals	Fuels	Total	Per Capita Value of Mineral Production	Population of Canada
			($ million)		($)	(thousand)
1936	260	43	60	363	33.11	10 950
1937	335	57	66	458	41.48	11 045
1938	324	54	65	443	39.71	11 152
1939	343	61	71	475	42.12	11 267
1940	382	69	79	530	46.55	11 381
1941	395	80	85	560	48.69	11 507
1942	392	83	92	567	48.63	11 654
1943	357	80	93	530	44.94	11 795
1944	308	81	97	486	40.67	11 946
1945	317	88	94	499	41.31	12 072
1946	290	110	103	503	40.91	12 292
1947	395	140	110	645	51.38	12 551
1948	488	172	160	820	63.97	12 823
1949	539	178	184	901	67.01	13 447
1950	617	227	201	1 045	76.24	13 712
1951	746	266	233	1 245	88.90	14 009
1952	728	293	264	1 285	88.90	14 459
1953	710	312	314	1 336	90.02	14 845
1954	802	333	353	1 488	97.36	15 287
1955	1 008	373	414	1 795	114.37	15 698
1956	1 146	420	519	2 085	129.65	16 081
1957	1 159	466	565	2 190	131.87	16 610
1958	1 130	460	511	2 101	122.99	17 080
1959	1 371	503	535	2 409	137.79	17 483
1960	1 407	520	566	2 493	139.48	17 870
1961	1 387	542	674	2 603	142.72	18 238
1962	1 496	574	811	2 881	155.05	18 583
1963	1 510	632	885	3 027	159.91	18 931
1964	1 702	690	973	3 365	174.45	19 290
1965	1 908	761	1 046	3 715	189.11	19 644
1966	1 985	844	1 152	3 981	198.88	20 015
1967	2 285	861	1 235	4 381	214.99	20 378
1968	2 493	886	1 343	4 722	228.11[r]	20 701
1969	2 378	891	1 465	4 734	225.42	21 001
1970	3 073	931	1 718	5 722	268.68	21 297
1971	2 940	1 008	2 015	5 963	276.46	21 569
1972	2 956	1 085	2 367	6 408	293.66	21 821
1973	3 850	1 292	3 227	8 369	378.77	22 095
1974	4 820	1 729[r]	5 202	11 751[r]	523.52[r]	22 446
1975	4 794	1 900	6 653	13 347	585.39	22 800
1976[p]	5 241	2 158	7 994	15 393	666.08	23 110

[p] Preliminary; [r] Revised.

Table 3. Canada, value of mineral production by provinces, territories and mineral classes, 1976ᵖ

	Metals		Industrial Minerals		Fuels		Total	
	$000	% of total	$000	% of total	$000	% of total	$000	% of total
Alberta	—	—	166 023	7.69	6 829 549	85.44	6 995 572	45.45
Ontario	2 153 488	41.09	428 766	19.87	11 788	0.15	2 594 042	16.85
Quebec	765 699	14.61	755 620	35.01	2	. .	1 521 321	9.88
British Columbia	710 487	13.56	143 576	6.65	567 033	7.09	1 421 096	9.23
Saskatchewan	25 116	0.48	420 826	19.50	462 612	5.79	908 554	5.90
Newfoundland	699 919	13.35	56 088	2.60	—	—	756 007	4.91
Manitoba	387 330	7.39	57 795	2.68	32 995	0.41	478 120	3.11
New Brunswick	217 945	4.16	30 729	1.42	6 383	0.08	255 057	1.66
Northwest Territories	185 158	3.53	—	—	27 942	0.35	213 100	1.39
Yukon	96 009	1.83	34 460	1.60	600	0.01	131 069	0.85
Nova Scotia	—	—	62 701	2.90	54 500	0.68	117 201	0.76
Prince Edward Island	—	—	1 700	0.08	—	—	1 700	0.01
Total Canada	5 241 151	100.00	2 158 284	100.00	7 993 404	100.00	15 392 839	100.00

ᵖPreliminary; — Nil; . . Not available or applicable.

Table 4. Canada, production of leading minerals

	Unit of Measure	Nfld.	P.E.I.	N.S.	N.B.	Quebec	Ontario
Petroleum, crude	000 m³	—	—	—	1	—	100
	$000	—	—	—	24	—	6 028
Natural gas	000 m³	—	—	—	2 775	255	141 584
	$000	—	—	—	59	2	5 760
Iron ore	000 t	27 970	—	—	—	17 754	10 369
	$000	643 455	—	—	—	324 607	264 111
Nickel	000 t	—	—	—	—	—	211
	$000	—	—	—	—	—	993 704
Copper	000 t	7	—	—	10	120	259
	$000	10 194	—	—	14 587	181 500	390 361
Zinc	000 t	46	—	—	172	123	320
	$000	37 833	—	—	142 432	101 960	265 426
Natural gas byproducts	000 m³	—	—	—	—	—	—
	$000	—	—	—	—	—	—
Coal	000 t	—	—	1 996	290	—	—
	$000	—	—	54 500	6 300	—	—
Asbestos	000 t	86	—	—	—	1 263	26
	$000	33 383	—	—	—	343 164	3 797
Potash (K_2O)	000 t	—	—	—	—	—	—
	$000	—	—	—	—	—	—
Cement	000 t	. .	—	. .	. .	2 683	3 764
	$000	5 014	—	7 059	8 967	88 733	116 162
Sand and gravel	000 t	5 080	816	8 618	3 538	83 007	68 039
	$000	9 200	1 700	14 400	4 100	75 900	95 200
Stone	000 t	816	—	1 451	2 540	51 710	26 853
	$000	2 700	—	4 400	7 000	117 000	66 500
Gold	kg	405	—	—	125	14 743	22 830
	$000	1 596	—	—	460	58 460	90 414
Silver	kg	15 925	—	—	156 109	114 679	486 552
	$000	2 194	—	—	21 497	15 794	67 000
Lead	t	9 253	—	—	61 687	923	6 379
	$000	4 621	—	—	30 808	460	3 186
Clay products	$000	475	—	3 915	2 464	14 243	50 926
Molybdenum	t	—	—	—	—	461	—
	$000	—	—	—	—	2 946	—
Salt	000 t	—	—	902	—	—	4 246
	$000	—	—	17 632	—	—	44 272
Titanium dioxide	000 t	—	—	—	—	. .	—
	$000	—	—	—	—	74 410	—
Iron, remelt	000 t	—	—	—	—	. .	—
	$000	—	—	—	—	65 086	—
Sulphur, elemental	000 t	—	—	—	—	—	2
	$000	—	—	—	—	—	35
Lime	000 t	—	—	—	. .	622	916
	$000	—	—	—	1 440	20 570	24 236
Platinum group	kg	—	—	—	—	—	13 375
	$000	—	—	—	—	—	48 790
Sodium sulphate	000 t	—	—	—	—	—	—
	$000	—	—	—	—	—	—
Total leading minerals	$000	750 665	1 700	101 906	240 138	1 484 835	2 535 908
Total all minerals	$000	756 007	1 700	117 201	255 057	1 521 321	2 594 042
Leading minerals as	% of all minerals	99.3	100.0	87.0	94.2	97.6	97.8

[p] Preliminary; — Nil; . . Not available.

by provinces and territories, 1976[p]

Manitoba	Sask.	Alberta	B.C.	Yukon	N.W.T.	Total Canada
626	8 824	65 799	2 337	—	156	77 843
32 995	435 675	3 531 100	114 272	—	8 364	4 128 458
—	1 608 397	73 652 127	10 498 755	28 317	925 961	86 858 171
—	8 250	2 302 235	130 137	600	19 578	2 466 621
—	—	—	809	—	—	56 902
—	—	—	9 090	—	—	1 241 263
51	—	—	—	—	—	262
238 439	—	—	—	—	—	1 232 143
57	9	—	273	11	1	747
85 444	14 463	—	412 308	16 639	660	1 126 156
62	8	—	113	52	144	1 040
51 367	6 775	—	93 940	42 898	119 685	862 296
—	135	16 055	353	—	—	16 543
—	5 787	772 414	16 124	—	—	794 325
—	4 627	10 687	7 711	—	—	25 311
—	12 900	223 800	306 500	—	—	604 000
—	—	—	71	103	—	1 549
—	—	—	30 719	34 460	—	445 523
—	5 126	—	—	—	—	5 126
—	361 442	—	—	—	—	361 442
586	327	1 048	919	—	—	9 850
22 606	15 171	36 948	38 499	—	—	339 159
17 418	7 439	23 133	30 572	—	—	247 660
25 200	10 200	42 100	42 800	—	—	320 800
454	—	181	3 175	—	—	87 180
1 500	—	1 200	9 300	—	—	209 600
1 431	591	—	5 506	965	5 848	52 444
5 674	2 342	—	21 820	3 910	23 120	207 796
27 714	10 078	—	254 956	97 634	108 085	1 271 732
3 817	1 387	—	35 108	13 446	14 885	175 128
275	—	—	88 633	38 254	53 679	259 083
137	—	—	44 264	19 104	26 808	129 388
1 318	3 098	8 727	6 944	—	—	92 110
—	—	—	13 955	—	—	14 416
—	—	—	88 927	—	—	91 873
28	281	295	—	—	—	5 752
161	7 833	5 793	—	—	—	75 691
—	—	—	—	—	—	. .
—	—	—	—	—	—	74 410
—	—	—	—	—	—	. .
—	—	—	—	—	—	65 086
1	15	3 720	43	—	—	3 781
15	293	62 280	716	—	—	63 339
. .	—	132	34	—	—	1 825
2 805	—	4 093	955	—	—	54 099
—	—	—	—	—	—	13 375
—	—	—	—	—	—	48 790
—	. .	. .	—	—	—	490
—	22 221	2 657	—	—	—	24 878
471 478	907 817	6 993 347	1 402 423	131 057	213 100	15 234 374
478 120	908 554	6 995 572	1 421 096	131 069	213 100	15 392 839
98.6	99.9	99.9	98.7	100.0	100.0	99.0

Table 5. Canada, percentage contribution of leading minerals to total value of mineral production, 1967-76

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]
Petroleum, crude	19.8	19.8	21.4	20.2	22.8	24.5	26.8	30.0	28.2	26.8
Natural gas	4.5	4.8	5.5	5.5	5.7	6.2	5.4	6.2	11.4	16.0
Iron ore	10.7	11.3	9.6	10.3	9.3	7.6	7.2	6.2	6.9	8.1
Nickel	10.6	11.2	10.2	14.5	13.4	11.2	9.7	8.3	8.3	8.0
Copper	13.3	12.9	12.4	13.6	12.7	12.6[r]	13.8	11.9	7.7	7.3
Zinc	7.3	6.9	7.8	7.0	7.0	7.5	7.8	7.4	6.5	5.6
Natural gas by-products	2.6	2.8	2.9	2.8	3.2	3.9	4.2	5.6	5.9	5.2
Coal	1.3	1.1	1.1	1.5	2.0	2.4	2.1	2.6	4.4	3.9
Asbestos	3.7	3.9	4.1	3.6	3.4	3.2	2.8	2.6	2.0	2.9
Potash (K_2O)	1.5	1.4	1.5	1.9	2.3	2.1	2.1	2.6	2.7	2.4
Cement	3.3	3.1	3.4	2.7	3.1	3.3	2.9	2.4[r]	2.4	2.2
Sand and gravel	3.3	2.7	2.6	2.3	2.6	2.8	2.6[r]	2.3	2.3	2.1
Stone	2.3	2.0	1.9	1.5	1.6	1.6	1.5	1.5	1.5	1.4
Gold	2.5	2.2	2.0	1.5	1.3	1.9	2.3	2.2	2.0	1.3
Silver	1.4	2.2	1.8	1.4	1.2	1.2	1.4	1.7	1.3	1.1
Lead	2.0	1.9	2.0	2.2	1.8	1.8	1.5	1.1	1.2	0.8
Clay products	1.0	1.0	1.1	0.9	0.8	0.8	0.7	0.6	0.6	0.6
Molybdenum	0.9	0.8	1.1	1.0	0.6	0.7	0.6	0.5	0.5	0.6
Salt	0.6	0.7	0.6	0.6	0.7	0.6	0.6	0.5	0.5	0.5
Titanium dioxide	0.5	0.6	0.6	0.6	0.7	0.6	0.6	0.4	0.4	0.5
Iron, remelt	0.4	0.5	0.6	0.6	0.5	0.7	0.6	0.6	0.6	0.4
Sulphur, elemental	1.6	1.7	1.3	0.5	0.4	0.3	0.3	0.6	0.7	0.4
Lime	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Platinum group	0.8	1.0	0.7	0.8	0.7	0.5	0.5	0.5	0.4	0.3
Sodium sulphate	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Other minerals	3.5	2.9	3.2	2.0	1.7	1.5	1.5	1.2	1.0	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[p] Preliminary; [r] Revised.

Table 6. Canada, value of mineral production by provinces and territories, 1967-76

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976^p
					($ millions)					
Alberta	974	1 092	1 205	1 396	1 641	1 979	2 760	4 517^r	5 746	6 996
Ontario	1 195	1 356	1 222	1 593	1 555	1 536	1 855	2 435^r	2 350	2 594
Quebec	741	725	717	803	766	786	936	1 222^r	1 240	1 521
British Columbia	380	389	434	490	541	678	978	1 156	1 297	1 421
Saskatchewan	362	357	345	379	410	410	510	791	862	909
Newfoundland	266	310	257	353	343	291	374	448	551	756
Manitoba	185	210	246	332	330	323	414	489^r	530	478
New Brunswick	90	88	95	105	107	120	164	217^r	232	255
Northwest Territories	118	116	119	134	116	120	165	223	206	213
Yukon	15	21	35	78	93	107	151	171	230	131
Nova Scotia	53	57	58	58	60	57	61	81	101	117
Prince Edward Island	2	1	1	1	1	1	2	1	2	2
Total	4 381	4 722	4 734	5 722	5 963	6 408	8 370	11 751^r	13 347	15 393

^{p}Preliminary; ^{r}Revised.

Table 7. Canada, percentage contribution of provinces and territories to total value of mineral production, 1967-76

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976^p
Alberta	22.2	23.1	25.5	24.4	27.5	30.9	33.0	38.4^r	43.1	45.4
Ontario	27.3	28.7	25.8	27.8	26.0	23.9	22.2	20.7	17.6	16.9
Quebec	16.9	15.4	15.2	14.0	12.9	12.3	11.2	10.4	9.3	9.9
British Columbia	8.7	8.2	9.2	8.6	9.1	10.6	11.7	9.8^r	9.7	9.2
Saskatchewan	8.3	7.6	7.3	6.6	6.9	6.4	6.1	6.7	6.5	5.9
Newfoundland	6.1	6.6	5.4	6.2	5.8	4.5	4.5	3.8	4.1	4.9
Manitoba	4.2	4.4	5.2	5.8	5.5	5.0	4.9	4.2^r	4.0	3.1
New Brunswick	2.1	1.9	2.0	1.8	1.8	1.9	1.9	1.9^r	1.7	1.7
Northwest Territories	2.7	2.5	2.5	2.4	1.9	1.9	2.0	1.9	1.5	1.4
Yukon	0.3	0.4	0.7	1.4	1.6	1.7	1.8	1.5	1.7	0.8
Nova Scotia	1.2	1.2	1.2	1.0	1.0	0.9	0.7	0.7	0.8	0.8
Prince Edward Island	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^{p}Preliminary; ^{r}Revised.

Table 8. Canada's world role as a producer of certain

	Year and Production Unit	World production
Nickel (mine production)	1975^p, tonnes % of world total	750 980
Zinc (mine production)	1975^p, tonnes % of world total	6 168 781
Asbestos	1975^p, tonnes % of world total	4 125 473
Silver	1975^p, kilograms % of world total	8 859 099
Potash K_2O (equivalent)	1975^p, 000 tonnes % of world total	24 115
Titanium concentrate (ilmenite)	1975^p, tonnes % of world total	3 340 689
Uranium (U_3O_8 concentrates)	1975^p, tonnes % of world total	24 025
Molybdenum	1975^p, tonnes % of world total	81 733
Gypsum	1975^p, 000 tonnes % of world total	54 752
Elemental sulphur	1975^p, 000 tonnes % of world total	32 592
Platinum group metals (mine production)	1975^p kilograms % of world total	178 413
Gold (mine production)	1975^p kilograms % of world total	1 201 109
Copper (mine production)	1975 tonnes % of world total	7 314 726
Lead (mine production)	1975 tonnes % of world total	3 592 000
Aluminum (primary metal)	1975 tonnes % of world total	12 701 523
Cadmium (smelter production)	1975^p tonnes % of world total	15 604
Iron ore[1]	1975^p 000 tonnes % of world total	886 011

[1]Canada is in seventh position with 5.1% of total world production in 1975.
^{p}Preliminary; ^{e}Estimated.

important minerals, 1975

Rank of six leading countries with % of world total

1	2	3	4	5	6
Canada 242 180 32.3	New Caledonia 133 300 17.8	U.S.S.R. 125 000[e] 16.6	Australia 75 800 10.1	Cuba 36 600 4.9	Dominican Rep. 26 900 3.6
Canada 1 229 481 19.9	U.S.S.R. 1 030 000[e] 16.7	Australia 502 600 8.2	U.S.A. 470 100 7.6	Peru 383 200 6.2	Japan 254 400 4.1
U.S.S.R. 1 900 000[e] 46.1	**Canada** 1 055 667 25.6	Republic of South Africa 354 170 8.6	Southern Rhodesia 165 000[e] 4.0	People's Rep. of China 150 000[e] 3.6	Italy 146 980 3.5
U.S.S.R. 1 337 450[e] 15.1	**Canada** 1 234 642 13.9	Mexico 1 182 834 13.4	Peru 1 175 183 13.3	U.S.A. 1 085 511 12.2	Australia 732 083 8.3
U.S.S.R. 7 802 32.4	**Canada** 4 673 19.4	East Germany 3 019 12.5	U.S.A. 2 269 9.4	West Germany 2 223 9.2	France 2 085 8.6
Australia 1 013 325 30.3	**Canada** 750 242 22.5	U.S.A. 650 707 19.5	Norway 526 904 15.8	Finland 122 600 3.7	Malaysia 115 000[e] 3.4
U.S.A. 10 523 43.8	**Canada** 5 517 22.9	Republic of South Africa 2 809 11.7	France 2 021 8.4	Niger 1 651 6.9	Gabon 1 097 4.6
U.S.A. 48 072 58.8	**Canada** 13 027 16.0	Chile 9 091 11.1	U.S.S.R. 9 072[e] 11.1	People's Rep. of China 1 497[e] 1.8	Peru 590 0.7
U.S.A. 8 846 16.2	France 5 813 10.6	**Canada** 5 719 10.5	U.S.S.R. 4 990[e] 9.1	Spain 4 173 7.6	United Kingdom 3 629 6.6
U.S.A. 10 345 31.8	Poland 4 754 14.6	**Canada** 4 079 12.5	U.S.S.R. 2 812 8.6	Mexico 2 149 6.6	France 1 832 5.6
U.S.S.R. 82 424[e] 46.2	Republic of South Africa 81 566 45.7	**Canada** 12 417 7.0	Colombia 688 0.4	Japan 605 0.3	U.S.A. 588 0.3
Republic of South Africa 713 446 59.4	U.S.S.R. 233 276[e] 19.4	**Canada** 51 433 4.3	U.S.A. 32 729 2.7	Papua-New Guinea 18 419 1.5	Ghana 16 295 1.4
U.S.A. 1 280 000 17.5	U.S.S.R. 1 100 000 15.0	Chile 828 300 11.3	**Canada** 733 826 10.0	Zambia 676 900 9.3	Zaire 494 800 6.8
U.S.S.R. 600 000[e] 16.7	U.S.A. 575 400 16.0	Australia 407 200 11.3	**Canada** 352 502 9.8	Mexico 179 400 5.0	Peru 166 500 4.7
U.S.A. 3 519 100 27.7	U.S.S.R. 2 150 000[e] 16.9	Japan 1 013 300 8.0	**Canada** 887 023 7.0	West Germany 677 600 5.3	Norway 594 900 4.7
U.S.S.R. 2 950[e] 18.9	Japan 2 688 17.2	U.S.A. 1 989 12.8	**Canada** 1 192 7.6	West Germany 1 017 6.5	Belgium 950 6.1
U.S.S.R. 232 800 26.3	Australia 99 400 11.2	U.S.A. 81 351 9.2	Brazil 69 640 7.9	People's Rep. of China 51 000 5.8	France 50 142 5.7

Table 9. Canada, census value added, commodity producing industries, 1968-74

	1968	1969	1970	1971	1972	1973	1974[p]
	($ million)						
Primary industries							
Agriculture	2 870	3 049[r]	2 820[r]	3 136[r]	3 327[r]	5 145[r]	5 961
Forestry	644	734	683	686	814	1 089[r]	1 221
Fishing	186	186[r]	204	205	237	320	291
Trapping	12	16	13	11	16	29	31
Mining[1]	3 176	3 342	3 805	3 810	4 267	6 264[r]	8 898
Electrical power	1 360	1 511	1 707	1 856	2 051	2 345	2 697
Total	8 248	8 838[r]	9 232[r]	9 704[r]	10 712[r]	15 192[r]	19 087
Secondary industries							
Manufacturing	18 332	20 134	20 048	21 737	24 265[r]	28 716[r]	35 085
Construction	5 269	5 794	6 167	7 581	8 244	9 695	11 850
Total	23 601	25 928	26 215	29 318	32 509[r]	38 411[r]	46 935
Grand Total	31 849	34 766[r]	35 447[r]	39 022[r]	43 221[r]	53 603[r]	66 022

[1]Cement, lime clay, and clay products (from domestic clays) in the above table are included under Manufacturing.
[p]Preliminary; [r]Revised.

Table 10. Canada, census value added, mining and mineral manufacturing industries, 1970-74

	1970	1971	1972	1973	1974p
			($ 000)		
Mining					
Metallic minerals					
Placer gold	120	92	110	. .	. .
Gold quartz	63 902	59 516	74 938	119 165	163 536
Copper-gold-silver	432 678	378 384	446 121	1 023 575	1 025 765
Silver-cobalt	4 184	2 874	3 587	. .[1]	. .[1]
Silver-lead-zinc	171 603	156 050	175 301	291 706	382 731
Nickel-copper	634 644	448 779	521 009	813 843	1 043 377
Iron	367 599	345 900	281 757	353 790	419 718
Miscellaneous metal mines	101 824	90 705	95 392	105 588	130 538
Total	1 776 554	1 482 300	1 598 215	2 707 667	3 165 665
Industrial minerals					
Asbestos	168 612	165 018	160 859	174 406	237 183
Feldspar, quartz and nepheline syenite	8 939	9 473	11 086	13 981	15 413
Gypsum	10 756	11 608	14 609	16 796	16 610
Peat	9 432	11 227	10 706	13 523	18 991
Potash	85 743	107 396	111 970	129 249	233 385
Salt	28 124	29 842	31 879	36 388	49 274
Sand and gravel	42 059	51 454	51 400	55 500	79 139
Stone	47 165	50 827	57 442	65 668	92 683
Talc and soapstone	784	897	1 174	1 464	1 417
Miscellaneous nonmetals	12 107	10 101	11 830	12 703	20 947
Total	413 721	447 843	462 955	519 678	765 042
Fuels					
Coal	74 035	103 918	130 144	164 858	256 626
Petroleum and natural gas	1 540 581	1 775 798	2 075 454	2 871 455	4 710 188
Total	1 614 616	1 879 716	2 205 598	3 036 313	4 966 814
Total mining industry	3 804 891	3 809 859	4 266 768	6 263 658	8 897 521
Mineral manufacturing					
Primary metal industries					
Iron and steel mills	835 956	866 948	909 369	1 154 569	1 385 329
Steel pipe & tube mills	76 558	86 564	113 801	117 375	148 759
Iron foundries	119 721	120 039	135 431	161 217	218 311
Smelting and refining	552 540	545 192	530 569	551 062	753 472
Aluminum rolling, casting and extruding	80 163	87 491	98 265	95 377	147 395
Copper and alloy rolling, casting & extruding	52 319	55 780	67 253	91 219	91 843
Metal rolling, casting and extruding, nes	51 831	50 144	62 630	80 093	101 279
Total	1 769 088	1 812 158	1 917 318	2 250 912	2 846 388
Nonmetallic mineral products industries					
Cement manufacturers	115 175	131 404	155 968	171 517	190 231
Lime manufacturers	11 248	11 937	12 605	17 858	24 982
Gypsum products manufacturers	31 874	40 395	. .[2]	. .[2]	. .[2]
Concrete products manufacturers	125 170	160 480	175 927	191 630	241 526
Ready-mix concrete manufacturers	108 467	133 290	156 206	195 321	223 159
Clay products (domestic clay)	32 553	37 514	39 572	41 239	51 248
Clay products (imported clay)	21 947	22 791	26 546	33 410	40 671
Refractories manufacturers	23 212	20 741	19 375	24 652	32 029

Table 10. (concl'd)

	1970	1971	1972	1973	1974p
			($ 000)		
Stone products manufacturers	5 960	10 622	9 330	10 898	12 287
Mineral wool manufacturers	24 692	29 535	. .[2]	. .[2]	. .[2]
Asbestos products manufacturers	31 600	37 269	. .[2]	. .[2]	. .[2]
Glass manufacturers	104 955	123 390	143 531	158 024	193 164
Glass products manufacturers	44 434	55 878	58 248	72 716	69 677
Abrasive manufacturers	31 037	27 944	32 713	37 373	44 960
Other nonmetallic mineral products industries	11 415	12 497	143 197	154 738	172 133
Total	723 739	855 687	973 218	1 109 376	1 296 067
Mineral manufacturing					
Primary metal industries					
Iron and steel mills	835 956	866 948	909 369	1 154 569	1 385 329
Steel pipe & tube mills	76 558	86 564	113 801	117 375	148 759
Iron foundries	119 721	120 039	135 431	161 217	218 311
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Concrete products manufacturers	125 170	160 480	175 927	191 630	241 526
Ready-mix concrete manufacturers	108 467	133 290	156 206	195 321	223 159
Clay products (domestic clay)	32 553	37 514	39 572	41 239	51 248
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Refractories manufacturers	23 212	20 741	19 375	24 652	32 029
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Mineral wool manufacturers	24 692	29 535	. .[2]	. .[2]	. .[2]
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Glass manufacturers	104 955	123 390	143 531	158 024	193 164
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Other nonmetallic mineral products industries	11 415	12 497	143 197	154 738	172 133
Total	723 739	855 687	973 218	1 109 376	1 296 067
Petroleum and coal products industries					
Petroleum refining	331 965	401 032	431 301	537 380	922 454
Manufacturers of lubricating oil and greases	15 908	17 495	19 529	21 181	23 889
Other petroleum and coal products industries	8 355	10 629	11 735	15 367	21 319
Total	356 228	429 156	462 565	573 928	967 662
Total mineral manufacturing	2 849 005	3 097 001	3 353 101	3 934 216	5 110 117
Total mining and mineral manufacturing	6 653 946	6 906 860	7 619 869	10 197 874	14 007 638

[1]Included with "Silver-lead-zinc" mines; [2]Included with "Other nonmetallic mineral products industries."
pPreliminary; . . Not available; nes Not elsewhere specified.

Table 11. Canada, indexes of total industrial production, mining and mineral manufacturing, 1962-76 (1971=100)

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]
Total industrial production	58.6	62.3	68.0	73.8	79.2	82.3	87.6	93.6	94.9	100.0	107.2	116.8	120.5	114.8	120.5
Total mining	59.6	62.2	67.0	70.5	74.1	79.9	86.2	86.9	98.7	100.0	106.5	118.9	118.3	109.3	110.4
Metals															
All metals	71.3	70.7	75.5	78.0	81.5	89.9	95.5	88.4	105.4	100.0	97.8	110.3	110.5	102.8	108.3
Placer gold and gold quartz mines	173.9	167.2	164.6	159.7	150.0	134.1	121.7	118.2	105.3	100.0	90.9	81.1	69.9	71.2	74.6
Iron mines	45.4	54.6	65.6	65.9	82.7	88.8	104.8	91.9	116.1	100.0	89.3	114.9	112.9	112.5	139.4
Miscellaneous metal mines, nes	63.7	60.4	66.7	76.5	76.5	87.8	92.0	85.3	103.0	100.0	100.3	110.5	111.9	101.9	102.2
Fuels															
All fuels	45.7	49.1	53.2	56.8	61.3	67.1	73.4	80.8	92.6	100.0	118.3	134.0	127.9	118.3	111.8
Coal	66.7	71.2	74.8	75.1	70.7	70.3	68.7	68.4	87.5	100.0	148.3	160.6	158.4	201.7	193.8
Crude petroleum and natural gas	44.2	47.6	51.7	55.5	60.7	66.8	73.7	81.7	93.0	100.0	115.8	131.8	125.4	111.5	105.1
Nonmetals															
All nonmetals	48.7	54.6	61.0	65.6	71.8	76.8	83.7	92.8	95.0	100.0	100.8	108.5	124.6	103.6	118.1
Asbestos	64.9	69.0	74.0	71.7	79.5	78.9	82.6	89.8	95.2	100.0	102.0	104.6	110.4	71.9	104.9
Mineral manufacturing															
Primary metals	63.9	68.4	76.8	84.4	87.9	84.5	92.9	94.9	100.9	100.0	103.5	111.2	119.8	108.6	105.4
Nonmetallic mineral products	68.0	68.4	76.0	83.3	86.0	80.7	87.1	90.5	86.6	100.0	106.7	118.3	123.3	118.3	121.3
Petroleum and coal products	67.1	72.4	72.9	75.7	79.2	79.9	88.7	92.1	94.4	100.0	110.8	123.6	127.4	124.1	127.1

[p] Preliminary; nes Not elsewhere specified.

Table 12. Canada, indexes of real domestic product by industries, 1966-76 (1971=100)

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]
Real domestic product, all industries	79.5	82.3	86.9	92.2	94.4	100.0	105.5	113.0	117.6	118.7	124.2
Agriculture	96.7	78.9	85.2	90.6	89.0	100.0	87.9	90.2	80.6	89.2	100.4
Forestry	88.3	90.1	94.4	102.4	103.3	100.0	102.4	122.1	119.6	97.5	108.5
Fishing and trapping	107.5	102.0	115.6	102.6	105.4	100.0	95.5	100.4	89.8	86.0	102.0
Mining (including milling), quarries and oil wells	74.1	79.9	86.2	86.9	98.7	100.0	106.5	118.9	118.3	109.3	110.4
Electric power, gas and water utilities	67.9	72.6	78.2	85.4	93.3	100.0	110.5	119.6	127.4	126.7	137.8
Manufacturing	81.5	83.9	89.1	95.8	94.5	100.0	106.9	116.1	120.1	114.2	120.0
Construction	88.5	87.1	90.1	92.5	90.9	100.0	102.3	107.3	112.1	116.3	116.6
Transportation, storage and communication	73.1	77.9	82.8	89.0	94.2	100.0	106.9	115.7	122.8	125.2	130.5
Trade	80.2	83.7	87.1	91.7	93.2	100.0	108.9	117.6	125.5	125.9	133.1
Community, business and personal service	75.0	81.4	85.7	91.6	95.5	100.0	105.3	110.5	115.9	122.0	127.7
Finance, insurance and real estate	78.8	81.7	86.7	92.4	94.6	100.0	105.2	112.1	118.1	122.3	128.2
Public administration and defence	82.7	86.8	89.1	91.6	95.2	100.0	104.2	109.8	114.1	118.8	122.8

[p] Preliminary.

Table 13. Canada, value of exports of crude minerals and fabricated mineral products, by main groups, 1972-76

	1972	1973	1974	1975	1976[p]
			($ million)		
Ferrous					
Crude material	371.8	497.7	573.9	717.9	983.1
Fabricated material	485.9	551.1	913.1	909.6	996.8
Total	857.7	1 048.8	1 487.0	1 627.5	1 979.9
Nonferrous					
Crude material	1 014.1	1 498.9	1 799.3	1 513.2	1 521.8
Fabricated material[1]	1 388.9	1 673.0	2 089.3	1 831.9	2 196.0
Total	2 403.0	3 171.9	3 888.6	3 345.1	3 717.8
Nonmetals					
Crude material	475.5	594.1	792.5	792.1	1 091.3
Fabricated material	133.2	167.3	174.8	160.8	193.2
Total	608.7	761.4	967.3	952.9	1 284.5
Mineral Fuels					
Crude material	1 420.9	1 998.4	4 219.6	4 637.2	4 464.0
Fabricated material	209.5	311.5	615.1	638.5	557.6
Total	1 630.4	2 309.9	4 834.7	5 275.7	4 021.6
Total minerals and products					
Crude material	3 282.3	4 589.1	7 385.3	7 660.4	8 060.2
Fabricated material	2 217.5	2 702.9	3 792.3	3 540.8	3 943.6
Total	5 499.8	7 292.0[r]	11 177.6	11 201.2	12 003.8

[1] Includes gold, refined and unrefined.
[p] Preliminary; [r] Revised.

Table 14. Canada, value of imports of crude minerals and fabricated mineral products, by main groups, 1972-76

	1972	1973	1974	1975	1976[p]
			($ million)		
Ferrous					
Crude material	53.1	75.3	94.6	179.5	129.8
Fabricated material	850.4	1 022.1	1 759.8	1 494.6	1 281.7
Total	903.5	1 097.4	1 854.4	1 674.1	1 411.5
Nonferrous					
Crude material[1]	185.8	255.1	302.7	288.9	294.6
Fabricated material[1]	343.7	474.0	816.2	622.1	600.6
Total	529.5	729.1	1 118.9	911.0	895.2
Nonmetals					
Crude material	71.6	89.0	120.7	183.0	161.5
Fabricated material	198.7	243.1	326.1	359.0	413.8
Total	270.3	332.1	446.8	542.0	575.3
Mineral fuels					
Crude material	867.6	1 116.1	2 955.5	3 888.4	3 830.9
Fabricated material	209.2	214.5	373.6	275.8	219.7
Total	1 076.8	1 330.6	3 329.1	4 164.2	4 050.6
Total minerals and products					
Crude material	1 178.1	1 535.5	3 473.5	4 539.8	4 416.8
Fabricated material	1 602.0	1 953.7	3 275.7	2 751.5	2 515.8
Total	2 780.1	3 489.2	6 749.2	7 291.3	6 932.6

[1]Includes gold, refined and unrefined.
[p]Preliminary.

Table 15. Canada, value of exports of crude minerals and fabricated mineral products in relation to total export trade, 1972-76

	1972		1973[r]		1974		1975		1976[p]	
	$ million	% of total	$ million	% of total	$ million	% of total	$ million	% of total	$ million	% of total
Crude material[1]	3 282.3	16.7	4 589.1[r]	18.5[r]	7 385.3	23.3	7 660.4	23.7	8 060.2	21.6
Fabricated material[1]	2 217.5	11.3	2 702.9[r]	10.9[r]	3 792.3	12.0	3 540.8	11.0	3 943.6	10.6
Total[1]	5 499.8	28.0	7 292.0[r]	29.4[r]	11 177.6	35.3	11 201.2	34.7	12 003.8	32.2
Total exports, all products[1]	19 670.8	100.0	24 837.9[r]	100.0	31 674.5[r]	100.0	32 325.0	100.0	37 258.8	100.0

[1]Includes gold, refined and unrefined.
[p]Preliminary; [r]Revised.

Table 16. Canada, value of imports of crude minerals and fabricated mineral products in relation to total import trade, 1972-76

	1972		1973		1974		1975		1976[p]	
	$ million	% of total	$ million	% of total	$ million	% of total	$ million	% of total	$ million	% of total
Crude material[1]	1 178.1	6.3	1 535.5	6.6	3 473.5	11.0	4 539.8	13.1	4 416.8	11.8
Fabricated material[1]	1 602.0	8.6	1 953.7	8.4	3 275.7	10.3	2 751.5	7.9	2 515.8	6.7
Total	2 780.1	14.9	3 489.2	15.0	6 749.2	21.3	7 291.3	21.0	6 932.6	18.5
Total imports all products[1]	18 669.4	100.0	23 325.3[r]	100.0	31 692.1[r]	100.0	34 635.5	100.0	37 432.6	100.0

[1]Includes gold, refined and unrefined.
[p]Preliminary; [r]Revised.

Table 17. Canada, value of exports of crude minerals and fabricated mineral products, by main groups and destination, 1976[p]

	United Kingdom	United States	Other Countries	Total
	($ million)			
Ferrous materials and products	75.6	1 393.4	510.9	1 979.9
Nonferrous materials and products[1]	527.8	1 802.5	1 387.5	3 717.8
Nonmetallic mineral materials and products	49.7	678.9	555.9	1 284.5
Mineral fuels, materials and products	6.5	4 375.2	639.9	5 021.6
Total	659.6	8 250.0	3 094.2	12 003.8
Percentage	5.5	68.7	25.8	100.0

[1] Includes gold, refined and unrefined.
[p] Preliminary.

Table 18. Canada, value of imports of crude minerals and fabricated mineral products, by main groups and country of origin, 1976[p]

	United Kingdom	United States	Other Countries	Total
	($ million)			
Ferrous materials and products	88.0	914.8	408.7	1 411.5
Nonferrous materials and products[1]	26.8	502.3	366.1	895.2
Nonmetallic mineral materials and products	15.5	422.5	137.3	575.3
Mineral fuels, materials and products	3.5	710.3	3 336.8	4 050.6
Total	133.8	2 549.9	4 248.9	6 932.6
Percentage of total mineral imports	1.9	36.8	61.3	100.0

[1] Includes gold, refined and unrefined.
[p] Preliminary.

Table 19. Canada, value of exports of crude minerals and fabricated mineral products, by commodity and destination, 1976ᵖ

	U.S.A.	United Kingdom	E.F.T.A.[1]	E.E.C.[2]	Japan	Other Countries	Total
				($ 000)			
Aluminum	346 696	14 507	1 683	7 376	12 014	113 898	496 174
Asbestos	136 129	35 722	12 847	113 809	39 027	150 037	487 571
Copper	244 674	129 896	50 194	138 996	244 079	57 445	865 284
Fuels	4 267 637	1 062	7 401	27 541	548 226	33 305	4 885 172
Iron ore	602 968	53 410	3 933	180 951	59 253	19 948	920 463
Lead	28 628	14 968	1 187	10 340	18 825	11 804	85 752
Molybdenum	5 226	13 493	563	35 336	31 035	1 513	87 166
Nickel	449 919	229 855	122 424	61 476	43 797	59 419	966 890
Primary ferrous metals	112 433	5 784	306	29 341	2 226	24 436	174 526
Uranium	46 850	20 541	—	—	—	—	67 391
Zinc	239 794	33 218	799	156 665	45 160	41 713	517 349
All other minerals[3]	1 768 992	107 242	12 663	149 021	60 772	351 372	2 450 062
Total	8 249 946	659 698	214 000	910 852	1 104 414	864 890	12 003 800

[1]European Free Trade Association: includes Austria, Norway, Portugal, Sweden, Switzerland, Finland and Iceland. [2]European Economic Community: includes Belgium-Luxembourg, France, Italy, Netherlands, West Germany, Denmark and Ireland, but excludes the United Kingdom for purposes of this table. [3]Includes gold refined and unrefined.
ᵖPreliminary; — Nil.

Table 20. Canada, mineral production and consumption, and

	Unit of Measure	1973 Consumption	1973 Production	1973 Consumption as % of Production	1974 Consumption	1974 Production	1974 Consumption as % of Production
Metals							
Aluminum	tonnes	331 783	941 530	35.2	359 790	1 006 632	35.7
Antimony	kg	444 323	. .	. .	983 785	. .	. .
Bismuth	kg	25 788	32 062	80.4	29 278	111 006	26.4
Cadmium	kg	54 866	1 903 543	2.9	47 876	1 240 970	3.9
Chromium (chromite)	tonnes	34 501	—	. .	60 471	—	. .
Cobalt	kg	195 689	1 516 973	12.9	185 442	1 563 568	11.9
Copper	tonnes	230 981[1]	823 942	28.0	247 984[1]	821 380	30.2
Lead	tonnes	108 349[2]	341 953	31.7	99 734[2]	294 268	33.9
Magnesium	tonnes	6 615	6 205	106.6	6 216	5 956	104.4
Manganese ore	tonnes	170 616	—	. .	210 595	—	. .
Mercury	kg	32 959	430 913	7.7	37 786	482 622	7.8
Molybdenum (Mo content)	kg	2 011 552	13 785 336	14.6	1 673 146	13 941 775	12.0
Nickel	tonnes	10 761	249 047	4.3	11 567	269 071	4.3
Selenium	kg	10 176	236 373	4.3	13 825	273 132	5.1
Silver	kg	524 745	1 477 029	35.5	598 114	1 331 531	44.9
Tellurium	kg	554	41 859	1.3	445	56 387	0.8
Tin	tonnes	5 235	132	3 965.9	5 425	324	1 674.4
Tungsten (W content)	kg	462 531	2 104 850	22.0	534 958	1 613 700	33.2
Zinc	tonnes	113 279[2]	1 226 581	9.5	117 619[2]	1 127 008	10.4
Nonmetals							
Barite	tonnes	75 431	92 152	81.9	58 439	78 019	74.9
Feldspar	tonnes	6 330	—	. .	6 847	—	. .
Fluorspar	tonnes	195 713	136 985[e]	142.9	237 008	136 000[e]	174.3
Mica	kg	3 010 000	—	. .	3 124 000	—	. .
Nepheline syenite	tonnes	95 437	516 554	18.5	110 881	559 986	19.8
Phosphate rock	tonnes	2 204 789	—	. .	2 298 384	—	. .
Potash (K_2O)	tonnes	190 708[3]	4 453 767	4.3	202 039[3]	5 776 019	3.5
Sodium sulphate	tonnes	272 228	492 922	55.2	305 366	638 179	47.9
Sulphur elemental	tonnes	576 605	4 167 475	13.8	906 227	5 033 057	18.0
Talc, etc.	tonnes	38 362	73 931	51.9	41 126	85 952	47.9
Fuels							
Coal	tonnes	24 870 489	20 472 755	121.2	24 844 710	21 269 588	116.8
Natural gas	000 cm	34 826 520[4]	88 367 585	39.4	37 231 875[4]	86 272 607	43.2
Petroleum, crude	cm	97 207 390[5]	104 272 315	93.2	102 831 813[5]	97 741 735	105.2

Note: Unless otherwise stated, consumption refers to reported consumption of refined metals or nonmetallic minerals by consumers. Production of metals, in most cases, refers to production in all forms, and includes the recoverable metal content of ores, concentrates, matte, etc., and metal content of primary products recoverable at domestic smelters and refineries. Production of nonmetals refers to producers' shipments. For fuels, production is equivalent to actual output less waste.

[1]Producers domestic shipments of refined metal. [2]Includes primary and secondary refined metal. [3]Consumption of potash fertilizers for year ended June 30. [4]Domestic sales. [5]Refinery receipts.

[p]Preliminary; — Nil; . . Not available or not applicable; [e]Estimated.

the latter expressed as a per cent of production, 1973-76

1975			1976[p]		
Consumption	Production	Consumption as % of Production	Consumption	Production	Consumption as % of Production
293 280	887 023	33.1	331 000	633 428	52.3
454 164	. .	. .	. .	. .	. .
29 267	156 605	18.6	. .	154 000	. .
38 209	1 191 674	3.2	. .	1 292 000	. .
36 790	—	. .	30 783	—	. .
123 002	1 354 213	9.1	160 492	1 373 000	11.7
185 198[1]	733 826	25.2	206 205[1]	747 135	27.6
89 192[2]	349 133	25.6	. .[2]	259 000	. .
5 404	3 826	141.2	4 230	5 858	72.2
160 976	—	. .	238 629	—	. .
32 869	413 676	8.0	26 039	—	—
1 436 883	13 026 696	11.0	. .	14 416 000	. .
11 308	242 180	4.7	. .	262 000	. .
9 933	182 385	5.5	11 212	260 000	4.3
642 089	1 234 642	52.0	. .	1 271 732	. .
614	19 854	3.1	589	24 000	2.5
4 330	319	1 357.4	. .	275	. .
451 336	1 477 731	30.5	. .	. .	. .
98 280[2]	1 055 151	9.3	. .	1 039 688	. .
40 229	81 356	49.5	. .	100 266	. .
5 630	—	. .	. .	—	. .
202 126	64 000[e]	315.8	. .	64 000[e]	. .
3 718 000	. .	. .	. .	. .	. .
103 774	468 427	22.2	. .	541 000	. .
2 095 368	—	. .	. .	—	. .
206 813[3]	4 673 425	4.4	242 077[3]	5 126 000	4.7
256 385	472 196	54.3	. .	490 000	. .
832 702	4 078 780	20.4	. .	3 781 000	. .
40 532	66 029	61.4	. .	65 000	. .
26 126 654	25 258 956	103.4	. .	25 311 000	. .
37 526 031[4]	87 485 758	42.9	38 834 919[4]	86 858 171	44.7
98 739 939[5]	83 001 381	119.0	98 337 736[5]	77 843 000	126.3

Table 21. Canada, apparent consumption[1] of some

	Unit of Measure	1973 Apparent Consumption	1973 Production	1973 Consumption as % of Production	1974 Apparent Consumption	1974 Production	1974 Consumption as % of Production
Asbestos	tonnes	−3 353	1 690 063	. .	−4 848	1 643 763	. .
Cement	tonnes	8 931 058	10 093 100	88.5	9 688 012^r	10 585 105^r	93.3
Gypsum	tonnes	1 940 155	7 610 529	25.5	2 069 024	7 225 203	28.6
Iron ore	tonnes	12 520 267	47 498 480	26.4	11 669 824	46 784 500	24.9
Lime	tonnes	1 391 400	1 715 114	81.1	1 593 216^r	1 958 842^r	81.3
Quartz (silica)	tonnes	3 393 189	2 509 222	135.2	3 319 463	2 505 670	132.5
Salt	tonnes	3 477 847^e	5 048 145	68.9	3 975 513^e	5 446 720	73.0

[1] "Apparent consumption" is production, plus imports, less exports. [2] "Production" refers to producers' shipments.
^{r} Revised; ^{e}Estimated; ^{p}Preliminary; . . Not available.

minerals and relation to production[2], 1973-76

		1975			1976[p]		
	Unit of Measure	Apparent Consumption	Production	Consumption as % of Production	Apparent Consumption	Production	Consumption as % of Production
Asbestos	tonnes	−13 774	1 055 667	. .	87 984	1 549 000	5.7
Cement	tonnes	9 389 734[r]	9 965 111	94.2	9 244 555	9 850 000	93.8
Gypsum	tonnes	2 083 113	5 719 451	36.4	1 919 503	5 663 000	33.8
Iron ore	tonnes	13 703 104	44 892 530	30.5	15 237 262	56 902 000	26.8
Lime	tonnes	1 397 689	1 601 624	87.2	1 552 550	1 825 000	85.0
Quartz (silica)	tonnes	3 497 448	2 491 715	140.4	3 671 378	2 376 000	154.5
Salt	tonnes	5 533 450[e]	5 122 573	108.0	5 954 749	5 752 000	103.5

Table 22. Canada, domestic consumption of principal refined metals in relation to refinery production[1], 1967-76

	Unit of Measure	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]
Copper											
Domestic consumption[2]	tonnes	199 290	226 891	205 279	215 834	200 536	207 661	230 981	247 984	185 198	206 205
Production	tonnes	453 453	475 795	407 536	493 261	477 545	495 944	497 581	559 124	529 197	510 469
Consumption of production	%	44.0	47.7	50.4	43.8	42.0	41.9	46.4	44.4	35.0	40.3
Zinc											
Domestic consumption[3]	tonnes	100 232	107 575	110 150	98 306	103 722	121 732	113 279	117 619	98 280	. .
Production	tonnes	367 533	387 121	423 072	413 196	372 529	476 168	532 552	426 272	426 941	472 316
Consumption of production	%	27.3	27.8	26.0	23.8	27.8	25.6	21.3	27.6	23.0	. .
Lead											
Domestic consumption[3]	tonnes	85 233	85 874	96 084	84 765	85 835	78 559	108 349	99 734	89 192	. .
Production	tonnes	175 300	183 342	169 773	185 637	168 332	186 860	186 891	126 460	171 516	175 720
Consumption of production	%	48.7	46.8	56.6	45.7	51.0	42.0	58.0	78.9	52.0	. .
Aluminum											
Domestic consumption[4]	tonnes	197 298	219 893	244 057	250 150	292 188	302 591	331 783	359 790	293 280	331 000
Production	tonnes	873 930	888 290	978 596	962 541	1 002 116	918 191	941 530	1 006 632	887 023	633 428
Consumption of production	%	22.6	24.8	24.9	26.0	29.2	33.0	35.2	35.7	33.1	52.3

[1]Production of refined metal from all sources, including metal derived from secondary materials at primary refineries. [2]Producers' domestic shipments of refined metal. [3]Consumption of primary and secondary refined metal, reported by consumers. [4]Consumption of primary refined metal, reported by consumers.
[p]Preliminary; . . Not available.

Table 23. Average annual prices[1] of main metals, 1972-76

	Unit of Measure	1972	1973	1974	1975	1976
Aluminum, major U.S. producer	cents/lb	26.409	25.000	34.133	39.786	44.341
Antimony, RMM/Laredo	cents/lb	57.000	66.498	179.764	174.575	163.194
Bismuth, major producer	$/lb	3.63	4.92	8.41	7.72	7.500
Cadmium, U.S. producer	cents/lb	255.600	364.000	407.800	335.500	266.200
Calcium, metal crowns	$/lb	0.95	0.95	1.07	1.32	1.335
Chrome, U.S. metal, 9% carbon	$/lb	1.56	1.52	1.90	2.57	2.64
Cobalt metal, shot/cathode/ 250 kg	$/lb	2.45	3.01	3.47	4.00	4.51
Columbium, U.S. metallurgical powder	$/lb	11.00-22.00	11.00-22.00			
Copper, U.S. producer refinery	cents/lb	50.617	58.852	76.649	63.535	68.824
Gold, Royal Canadian Mint buying price	$ Cdn/tr. oz	36.58	38.86	41.18	43.22	39.83
London free market[2]	$ Cdn/tr. oz	57.53	97.25	155.67	163.78	123.24
Iridium, major producer	$/troy oz	150.00-178.33	227.08-235.42	410.67-409.17	475.00-485.00	316.66-326.66
Iron ore						
Bessemer						
Mesabi	$/lt	11.32	12.01	13.99	. .	. .
Old Range	$/lt	11.57	12.26	14.24	. .	. .
Non-Bessemer						
Mesabi	$/lt	11.17	11.86	14.00	17.89	18.50-19.67
Old Range	$/lt	11.42	12.13	14.26	18.14	18.75-19.92
Lead, U.S. producer	cents/lb	15.029	16.285	22.533	21.529	23.102
Manganese, U.S. metal, regular	cents/lb	33.250	33.250	41.771	54.000	55.333-57.000
Magnesium, U.S. primary ingot	cents/lb	37.250	38.250	60.548	82.000	89.537
Mercury, New York	$/flask (76 lb)	218.28	285.23	281.69	158.12	121.302
Molybdenum, red carbon powder	$/lb	4.00	. .	. .	. .	. .
Molybdenum, climax concentrate	$/lb	1.72	1.72	2.06	2.49	3.00
Nickel, major producer cathode	cents/lb	139.700	153.000	173.500	207.300	225.600
Osmium, major producer	$/troy oz	200.00-225.00	200.00-225.00	200.00-225.00	200.00-225.00	200.00-225.00
Palladium, major producer	$/troy oz	41.64	77.68	133.22	92.70	50.93
Platinum, major producer	$/troy oz	120.78	150.04	180.85	164.01	161.72
Rhenium U.S. producer powder	$/lb	975.00-1,400.00	887.50-1,050.00	737.50	570.52	540.000
Rhodium, major producer	$/troy oz	195.00-200.00	225.83-230.83	335.58-342.92	337.50-347.50	350.00-364.166
Ruthenium, major producer	$/troy oz	50.00-55.00	59.17-64.17	60.00-65.00	60.00-65.00	60.000-65.000
Selenium, major producer commercial	$/lb	9.00	9.17-10.33	16.33	18.00	18.00
Silver, Handy & Harman, N.Y.	cents/troy oz	168.455	255.756	470.798	441.852	435.346

Table 23. (concl'd)

	Unit of Measure	1972	1973	1974	1975	1976
Tantalum, U.S. rod	$/lb	36.00-50.00	30.00-40.00	41.25-56.17	46.75-60.50	52.000-80.000
Tellurium, major producer slab	$/lb	6.00	6.08	8.33	9.33	10.500-11.083
Tin, N.Y. market	cents/lb	177.474	227.558	396.266	339.818	349.241
Titanium U.S. sponge	$/lb	1.32	1.42-1.43	1.85	2.55	2.700
Titanium, slag	$/lt	50.00	50.83	60.00	75.00	90.00
Tungsten, U.S. hydrogen red metal	$/lb	5.32-6.89	4.97-6.74	8.06-9.75	10.21-12.01	10.087-12.337
Vanadium 90%, 100 lb lots	$/lb	. .	. .	. .	. .	. .
Zinc, U.S. prime western	cents/lb	17.753	20.658	35.945	38.959	37.010

[1]These prices except for gold, are in United States currency and are quoted from *Metals Week*. [2]Average of a.m. and p.m. fixings of the London Gold Market, converted to Canadian dollars.
. . Not available.

Table 24. Canada, wholesale price indexes of minerals and mineral products, 1973-76 (1935-39=100)

	1973	1974	1975	1976[p]
Iron and products	354.2	447.7	519.9	563.4
Pig iron	342.7	475.5	748.8	814.0
Rolling mill products	338.8	431.1	507.2	540.7
Iron foundries and pipe and tubing	358.9	452.4	557.1	603.9
Wire	416.3	507.1	620.6	612.9
Scrap iron and steel	388.8	740.6	529.7	532.5
Tinplate and galvanized steel	311.3	357.4	420.2	481.0
Nonferrous metal and products				
Total (including gold)	326.5	417.7	417.4	441.1
Total (excluding gold)	478.5	607.3	606.2	647.1
Copper and products	579.4	706.7	541.4	579.1
Lead and products	366.5	500.1	420.5	423.5
Silver	663.3	1 180.8	1 176.7	1 173.9
Tin	435.6	764.4	704.4	819.1
Zinc and products	536.8	785.4	842.0	836.0
Nonmetallic minerals and products	254.1	331.2	392.1	432.2
Clay and clay products	308.2	384.2	422.0	476.6
Pottery	439.2	476.0	493.4	533.7
Petroleum products	226.7	342.0	394.3	452.2
Asphalt	243.9	432.5	516.2	578.2
Asphalt shingles	152.8	189.6	216.9	. .
Plaster	213.3	247.6	276.3	301.2
Lime	394.5	497.0	625.2	686.4
Cement	233.5	271.6	322.8	377.5
Sand and gravel	234.7	273.1	327.3	349.6
Crushed stone	203.7	236.5	271.2	314.7
Building stone	314.0	336.1	364.8	415.2
Asbestos	414.4	550.8	679.4	790.0
General wholesale price index (all products)	376.9	461.3	491.6	512.6

[p]Preliminary.

Table 25. Canada, general wholesale price index and wholesale price indexes of mineral and nonmineral products, 1952-76 (1935-39=100)

	Mineral products			Nonmineral products					
	Iron Products	Nonferrous Metal Products	Nonmetallic Mineral Products	Vegetable Products	Animal Products	Textile Products	Wood Products	Chemical Products	General Wholesale Price Index
1952	219.0	172.9	173.9	210.3	248.2	251.5	291.0	180.1	226.0
1953	221.4	168.6	176.9	199.0	241.7	239.0	288.6	175.7	220.7
1954	213.4	167.5	177.0	196.8	236.0	231.1	286.8	176.4	217.0
1955	221.4	187.6	175.2	195.1	226.0	226.2	295.7	177.0	218.9
1956	239.8	199.2	180.8	197.3	227.7	230.2	303.7	180.1	225.6
1957	252.7	176.0	189.3	197.0	238.4	236.0	299.4	182.3	227.4
1958	252.6	167.3	188.5	198.1	250.7	229.0	298.5	183.0	227.8
1959	255.7	174.6	186.5	199.5	254.3	228.0	304.0	187.0	230.6
1960	256.2	177.8	185.6	203.0	247.6	229.8	303.8	188.2	230.9
1961	258.1	181.6	185.2	203.1	254.7	234.5	305.1	188.7	233.3
1962	256.2	192.1	189.1	211.6	262.5	241.2	315.9	190.5	240.0
1963	253.6	197.5	189.5	227.8	255.6	248.0	323.4	189.3	244.6
1964	256.4	205.9	190.9	223.3	250.8	248.4	330.9	191.2	245.4
1965	264.5	217.6	191.6	218.4	270.7	246.4	334.0	200.2	250.3
1966	268.0	229.9	193.7	225.9	296.2	251.5	337.8	207.1	259.5
1967	274.4	240.2	199.2	230.9	293.1	252.7	346.3	212.6	264.1
1968	276.8	250.8	206.0	230.8	294.6	256.5	367.9	213.7	269.9
1969	285.8	264.0	210.0	237.9	322.4	256.7	389.4	219.7	282.4
1970	305.1	281.0	215.7	238.4	326.0	257.0	377.5	225.7	286.4
1971	316.4	260.1	225.8	237.1	326.0	261.9	394.4	237.8	289.9
1972	325.0	262.9	233.6	249.2	371.8	278.3	436.0	245.5	310.3
1973	354.2	326.5	254.1	354.8	455.3	337.8	503.7	263.3	376.9
1974	447.7	417.7	331.2	485.6	493.0	423.1	563.1	325.3	461.3
1975	519.9	417.4	392.1	469.6	537.5	404.9	641.7	383.9	491.6
1976[p]	563.4	441.1	432.2	450.2	552.0	442.8	688.3	389.4	512.6

[p] Preliminary.

Table 26. Canada, mineral products industries, selling price indexes, 1973-76 (1971=100)

	1973	1974	1975	1976[p]
Iron and steel products industries				
Agricultural implements industry	111.4	128.1	155.1	165.6
Hardware, tool and cutlery manufacturers	106.5	122.2	137.9	147.3
Heating equipment manufacturers	108.2	121.9	137.3	146.9
Primary metal industries	117.5	147.7	160.8	169.5
Iron and steel mills	110.4	136.3	162.1	177.1
Steel pipe and tube mills	111.5	132.0	162.9	178.9
Iron foundries	109.5	141.6	168.4	181.0
Wire and wire products manufacturers	113.9	136.6	158.3	170.9
Nonferrous metal products industries				
Aluminum rolling, casting and extruding	100.5	129.1	145.4	155.8
Copper and alloy, rolling, casting and extruding	122.6	154.8	131.6	138.6
Jewellery and silverware manufacturers	149.4	216.3	234.1	235.2
Metal rolling, casting and extruding, nes	126.5	184.2	171.8	181.0
Nonmetallic mineral products industries				
Abrasives manufacturers	104.3	114.6	140.5	167.5
Cement manufacturers	107.6	122.2	146.3	171.1
Clay products manufacturers from imported clay	106.6	127.3	151.0	161.7
Glass and glass products manufacturers	104.9	114.5	127.1	138.6
Lime manufacturers	116.1	143.5	181.7	204.3
Concrete products manufacturers	109.8	129.7	151.9	161.5
Clay products from domestic clay	111.0	129.1	157.1	169.6
Petroleum and coal products industries	117.2	159.4	183.7	210.2
Petroleum refineries	117.5	160.1	184.5	211.5
Lubricating oils	112.0	132.7	149.8	155.8
Mixed fertilizers	117.2	167.4	204.0	176.9

Note: Industry selling price indexes reflect wholesale price trends of products or groups of products sold by the industries listed.
[p] Preliminary; nes Not elsewhere specified.

Table 27. Canada, principal statistics of the mining industry,[1] 1974

	Mining activity								Total activity[2]		
		Production and related workers			Costs						
	Esta-blish-ments	Em-ployees	Man-hours Paid	Wages	Fuel and Elec-tricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
Metals											
Placer gold[3]	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Gold quartz	22	4 716	9 733	47 597	5 950	36 774	206 259	163 536	5 665	59 366	163 590
Copper-gold-silver	45	13 878	29 251	169 800	39 972	583 443	1 649 179	1 025 765	18 137	231 328	1 028 643
Silver-lead-zinc	25	4 940	9 780	52 702	14 289	261 185	658 205	382 731	6 722	77 178	382 281
Nickel-copper	11	15 125	29 612	148 335	19 870	416 957	1 480 204	1 043 377	20 739	234 047	1 049 650
Iron	18	9 560	20 117	131 199	79 561	315 192	814 472	419 718	15 019	215 956	403 910
Misc. metal mines	11	2 667	5 551	30 551	8 624	43 442	182 604	130 538	3 756	44 657	143 301
Total	132	50 886	104 044	580 184	168 266	1 656 993	4 990 923	3 165 665	70 038	862 532	3 171 375
Nonmetals											
Asbestos	12	6 461	14 852	70 744	24 259	74 193	335 635	237 183	8 131	92 416	239 816
Feldspar, quartz and nepheline syenite	11	391	845	3 517	1 272	3 309	19 994	15 413	478	4 745	15 339
Gypsum	10	577	1 221	4 861	1 101	4 258	21 969	16 610	671	5 853	16 542
Peat	53	1 136	2 210	6 896	918	6 574	26 483	18 991	1 288	8 443	19 772
Potash	9	2 519	5 407	28 494	12 593	34 676	280 654	233 385	3 224	37 616	232 652
Salt	9	901	1 907	9 672	2 997	9 657	61 928	49 274	1 387	15 372	49 751
Sand and gravel	158	2 090	4 617	21 290	6 734	22 955	108 828	79 139	2 739	29 696	83 522
Stone	124	2 839	6 453	27 802	8 988	41 378	143 049	92 683	3 458	34 629	92 852
Talc and soapstone	4	84	186	611	169	586	2 171	1 417	109	843	1 412
Misc. nonmetals	13	769	1 507	7 073	3 242	4 241	28 430	20 947	910	8 590	20 711
Total	403	17 767	39 205	180 960	62 273	201 827	1 029 141	765 042	22 395	238 203	772 369
Fuels											
Coal	20	6 430	12 422	71 085	10 776	63 968	331 370	256 626	8 142	91 622	261 246
Petroleum and natural gas	883	4 845	10 326	62 307	44 452	81 688	4 836 328	4 710 188	18 155	257 969	4 724 990
Total	903	11 275	22 748	133 392	55 228	145 656	5 167 698	4 966 814	26 297	349 591	4 986 236
Total mining industry	1 438	79 928	165 997	894 536	285 767	2 004 476	11 187 762	8 897 521	118 730	1 450 326	8 929 980

[1]Excludes cement manufacturing, lime manufacturers, clay and clay products (domestic clays). These industries are included in the mineral manufacturing industries. Industry coverage is the same as in Tables 29, 31 and 33. [2]Total activity includes sales and head offices. [3]Placer gold no longer surveyed.
. . Not available.

Table 28. Canada, principal statistics of the mineral manufacturing industries,[1] 1974

	Mineral manufacturing activity								Total activity[2]		
		Production and related workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
Primary metal industries											
Iron and steel mills	47	42 091	91 870	513 882	124 842	1 593 651	3 036 163	1 385 329	54 253	701 909	1 398 735
Steel pipe and tube mills	26	4 866	10 289	51 227	6 267	300 282	447 134	148 759	5 845	65 016	152 339
Iron foundries	111	10 216	21 456	95 263	11 127	182 798	398 746	218 311	12 054	118 752	222 415
Smelting and refining	28	25 792	53 868	282 998	118 404	537 981	1 409 857	753 472	35 249	418 967	794 193
Aluminum rolling, casting and extruding	64	4 619	9 482	44 633	7 058	334 727	472 999	147 395	6 162	65 474	146 721
Copper and alloy rolling, casting and extruding	42	3 089	6 578	32 795	4 148	413 886	494 113	91 843	3 779	41 412	91 301
Metal rolling, casting and extruding	79	3 865	8 016	31 721	4 189	172 243	276 400	101 279	4 877	44 141	106 108
Total	397	94 538	201 559	1 052 519	276 035	3 535 568	6 535 412	2 846 388	122 219	1 455 671	2 911 812
Nonmetallic mineral products industries											
Cement manufacturers	26	2 833	6 113	35 266	60 514	51 064	297 540	190 231	4 666	59 403	190 396
Lime manufacturers	15	639	1 353	6 003	11 400	8 643	44 799	24 982	840	8 505	25 033
Gypsum product manufacturers	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Concrete product manufacturers	431	9 110	19 561	87 664	10 597	158 114	401 110	241 526	11 602	119 420	248 548
Ready-mix concrete manufacturers	346	7 160	15 359	79 753	14 978	268 548	506 075	223 159	9 219	105 551	236 308
Clay products manufacturers (domestic)	63	2 443	5 229	21 653	9 226	16 001	75 158	51 248	3 001	28 217	51 531
Clay products manufacturers (imported)	29	1 853	3 873	14 901	1 655	17 422	56 745	40 671	2 288	19 149	41 661
Refractories manufacturers	16	902	1 938	8 673	2 648	27 281	61 504	32 029	1 391	14 430	37 163
Stone product manufacturers	86	713	1 500	5 592	614	7 788	20 222	12 287	929	7 626	12 327
Glass and glass products manufacturers	95	10 115	20 753	93 920	17 829	130 641	398 524	262 841	12 915	128 444	262 405
Mineral wool manufacturers	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .

Table 28. (concl'd)

	Mineral manufacturing activity								Total activity		
		Production and related workers			Costs						
	Esta-blish-ments	Em-ployees	Man-hours Paid	Wages	Fuel and Elec-tricity	Materials and Supplies	Value of Production	Value Added	Em-ployees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
Asbestos products manufacturers	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
Abrasive manufacturers	19	2 087	4 307	20 123	10 240	52 377	105 816	44 960	2 676	27 113	45 962
Other nonmetallic mineral products industries	80	5 029	10 889	50 548	11 499	131 976	315 014	172 133	8 039	87 040	195 228
Total nonmetallic minerals	1 206	42 884	90 875	424 096	151 200	869 855	2 282 507	1 296 067	57 566	604 898	1 346 562
Petroleum and coal products industries											
Petroleum refining industry	43	6 782	14 934	95 683	33 471	4 317 929	5 057 234	922 454	15 967	238 439	925 246
Manufacture of lubricating oils and greases	15	336	708	3 288	529	54 393	72 967	23 889	514	5 800	26 289
Other petroleum and coal products industries	47	669	1 405	6 428	2 160	31 838	55 117	21 319	954	10 299	26 717
Total petroleum and coal products industry	105	7 787	17 047	105 399	36 160	4 404 160	5 185 318	967 662	17 435	254 538	978 252
Total mineral manufacturing industries	1 708	145 209	309 481	1 582 014	463 395	8 809 583	14 003 237	5 110 117	197 220	2 315 107	5 236 626

[1]Industry coverage is the same as in Tables 30, 32 and 34. [2]Includes sales and head offices.

nes Not elsewhere specified; . . Not available.

Table 29. Canada, principal statistics of the mining industry,[1] 1969-74

	Mining Activity								Total Activity[2]		
		Production and related workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
1969	1 686	71 368	151 072	513 708	126 999	931 354	4 400 637	3 342 285	102 088	804 839	3 355 312
1970	1 636	77 208	164 835	614 084	146 049	1 167 456	5 118 396	3 804 891	110 094	994 014	3 830 364
1971	1 662	76 701	158 835	646 900	164 332	1 223 982	5 198 173	3 809 859	110 410	1 015 661	3 826 264
1972	1 716	73 044	150 929	666 505	175 562	1 210 445	5 652 775	4 266 768	107 322	1 068 783	4 292 465
1973	1 626	75 165	156 960	751 878	215 096	1 551 560	8 030 314	6 263 658	111 443	1 214 871	6 288 935
1974	1 438	79 928	165 997	894 536	285 767	2 004 476	11 187 762	8 897 521	118 730	1 450 326	8 929 980

[1]Cement manufacturing, lime manufacturers, clay and clay products (domestic clays) are included in the mineral manufacturing industries. Industry coverage is the same as in Tables 27, 31 and 33. [2]Includes sales and head offices.

Table 30. Canada, principal statistics of the mineral manufacturing industries,[1] 1969-74

	Mineral Manufacturing Activity								Total Activity[2]		
		Production and related workers			Costs						
	Establishments	Employees	Man-hours Paid	Wages	Fuel and Electricity	Materials and Supplies	Value of Production	Value Added	Employees	Salaries and Wages	Value Added
	(number)	(number)	(000)	($000)	($000)	($000)	($000)	($000)	(number)	($000)	($000)
1969	1 802	128 263	272 947	890 911	232 861	3 689 337	6 581 618	2 677 454	178 474	1 348 463	2 757 052
1970	1 781	131 570	278 547	989 725	263 827	3 954 629	7 002 306	2 849 055	181 620	1 480 524	2 920 381
1971	1 813	131 044	276 629	1 063 861	288 016	4 192 544	7 551 956	3 097 001	181 122	1 595 437	3 166 347
1972	1 783	132 067	282 307	1 172 977	304 705	4 667 819	8 299 939	3 353 101	182 454	1 753 069	3 436 258
1973	1 749	138 177	295 213	1 347 918	349 521	5 735 529	9 914 174	3 934 216	188 498	1 970 456	4 039 415
1974	1 708	145 209	309 481	1 582 014	463 395	8 809 583	14 003 237	5 110 117	197 220	2 315 107	5 236 626

[1]Industry coverage in this table is the same as in Tables 28, 33 and 34. [2]Includes sales and head offices.

Table 31. Canada, consumption of fuel and electricity (quantity and value) in the mining industry,[1] 1974

	Unit	Metals	Nonmetals	Fuels	Total
Coal and coke	000 tonnes	186	28	. . .	214
	$000	3 811	206	13	4 030
Gasoline	000 m³	281	424	63	768
	$000	3 359	5 064	554	8 977
Fuel oil, kerosene, coal oil	000 m³	11 524	4 099	494	16 116
	$000	72 656	28 623	3 186	104 465
Liquified petroleum gases	000 m³	654	56	28	738
	$000	3 736	419	124	4 279
Natural gas	000 m³	329 070	684 418	106 131	1 119 619
	$000	6 984	7 897	1 878	16 759
Other fuels[2]	$000	50	—	—	50
Total value of fuels	$000	90 596	42 209	5 755	138 560
Electricity purchased	Million kWh	10 282	2 015	2 972	15 269
	$000	77 669	20 065	49 473	147 207
Total value of fuels and electricity purchased, all reporting companies	$000	168 265	62 274	55 228	285 767

[1]Cement and lime manufacturing and manufacturers of clay products (domestic clays), are included under mineral manufacturing, Tables 32 and 34. Industry coverage is the same as in Tables 27, 29 and 33. [2]Includes wood, manufactured gas, steam purchased and other miscellaneous fuels.
— Nil; . . . Amount too small to be expressed.
Note: Totals may not add due to rounding.

Table 32. Canada, consumption of fuel and electricity (quantity and value) in the mineral manufacturing industries,[1] 1974

	Unit	Primary Metals Industries	Nonmetallic Mineral Products Industries	Petroleum and Coal Products Industries	Total
Coal and coke	000 Mg	419	302	3	724
	$ 000	19 165	7 370	8	26 543
Gasoline	000 m³	192	736	16	944
	$ 000	2 006	8 284	211	10 501
Fuel oil, kerosene, coal oil	000 m³	13 953	11 182	286	25 422
	$ 000	67 384	53 803	1 637	122 824
Liquefied petroleum gas	000 m³	874	138	1	1 012
	$ 000	4 117	1 062	6	5 185
Natural gas	000 m³	2 369 384	1 911 756	728 564	5 009 704
	$ 000	54 167	41 258	10 817	106 242
Other fuels	$ 000	6 629	754	596	7 979
Total value of fuels	$ 000	153 468	112 531	13 275	279 274
Electricity purchased	Million kWh	17 727	4 106	2 715	24 548
	$ 000	122 567	38 671	22 885	184 123
Total value, fuels and electricity purchased, all reporting companies	$ 000	276 035	151 202	36 160	463 397

[1]Industry coverage is the same as in Tables 28, 30 and 34.
Note: Totals may not add due to rounding.

Table 33. Canada, cost of fuel and electricity used in the mining industry,[1] 1967-74

	Unit	1967	1968	1969	1970	1971	1972	1973	1974
Metals									
Fuel	$000	26 116	29 340	27 070	33 370	39 887	40 492	54 430	90 596
Electricity purchased	million kWh	6 300	7 020	7 073	7 995	8 692	8 807	10 032	10 282
	$000	38 342	42 340	46 002	52 257	56 847	58 104	68 089	77 669
Total cost of fuel and electricity	$000	64 458	71 680	73 072	85 627	96 734	98 596	122 519	168 265
Electricity generated for own use and for sale	million kWh	510	466	476	459	359	446	. .	. .
Nonmetals[2]									
Fuel	$000	16 180	18 448	19 793	20 029	22 951	25 277	29 101	42 209
Electricity purchased	million kWh	1 127	1 291	1 473	1 468	1 584	1 642	1 782	2 015
	$000	9 537	10 809	12 728	13 980	14 474	15 080	16 593	20 065
Total cost of fuel and electricity	$000	25 717	29 257	32 521	34 009	37 425	40 357	45 694	62 274
Electricity generated for own use and for sale	million kWh	151	156	173	161	178	194	. .	. .
Fuels									
Fuels	$000	690	678	739	2 072	2 635	4 103	4 600	5 755
Electricity purchased	million kWh	989	1 101	1 265	1 540	1 763	2 154	2 792	2 972
	$000	16 126	17 662	20 244	23 320	27 528	32 494	42 283	49 473
Total cost of fuel and electricity	$000	16 816	18 340	20 983	25 392	30 163	36 597	46 883	55 228
Electricity generated for own use and for sale	million kWh	—	—	—	—	—	—	—	—
Total mining industry									
Fuel	$000	42 986	48 466	47 602	55 470	65 473	69 872	88 131	138 560
Electricity purchased	million kWh	8 416	9 412	9 811	11 003	12 039	12 603	14 606	15 267
	$000	64 005	70 811	78 974	90 558	98 849	105 678	126 965	147 207
Total cost of fuel and electricity	$000	106 991	119 277	126 576	146 028	164 322	175 550	215 096	285 767
Electricity generated for own use and for sale	million kWh	661	622	649	620	537	640	. .	. .

[1]Cement and lime manufacturing and manufacture of clay products (domestic clays) are included in mineral manufacturing, Tables 32 and 34. Industry coverage is the same as in Tables 27, 29 and 31. [2]Includes structural materials . . Not available; — Nil.

Table 34. Canada, cost of fuel and electricity used in the mineral manufacturing industries,[1] 1967-74

	Unit	1967	1968	1969	1970	1971	1972	1973	1974
Primary metals									
Fuel	$000	71 133	73 938	69 185	83 034	92 903	90 850	103 321	153 468
Electricity purchased	million kWh	13 118	14 363	15 370	14 539	15 028	15 678	16 584	17 727
	$000	60 624	68 834	73 114	87 656	90 512	95 447	108 575	122 567
Cost of fuel and electricity for small establishments[2]	$000	199	171	202	—	—	—	—	—
Total cost of fuel and electricity	$000	131 956	142 943	142 501	170 690	183 415	186 297	211 896	276 035
Nonmetallic mineral products									
Fuel	$000	44 055	45 237	47 310	49 451	57 249	65 166	75 144	112 531
Electricity purchased	million kWh	2 987	3 118	3 182	3 270	3 279	2 280	4 080	4 106
	$000	19 962	21 566	23 297	24 507	25 932	29 367	34 624	38 671
Cost of fuel and electricity for small establishments[2]	$000	852	1 165	1 231	—	—	—	—	—
Total cost of fuel and electricity	$000	64 869	67 968	71 838	73 958	93 181	94 533	109 768	151 202
Petroleum and coal products									
Fuel	$000	2 980	5 294	5 450	4 749	5 346	6 431	7 796	13 275
Electricity purchased	million kWh	1 659	1 818	1 980	2 171	2 326	2 475	2 683	2 715
	$000	10 699	11 467	13 059	14 430	16 074	17 444	20 061	22 885
Cost of fuel and electricity for small establishments[2]	$000	15	7	13	—	—	—	—	—
Total cost of fuel and electricity	$000	13 694	16 768	18 522	19 179	21 420	23 875	27 857	36 160
Total mineral manufacturing industries									
Fuel	$000	118 168	124 469	121 945	137 234	155 498	162 447	186 261	279 274
Electricity purchased	million kWh	17 764	19 299	20 532	19 980	20 633	20 433	23 347	24 548
	$000	91 285	101 867	109 470	126 593	132 518	142 258	163 260	184 123
Cost of fuel and electricity for small establishments[2]	$000	1 066	1 343	1 446	—	—	—	—	—
Total cost of fuel and electricity	$000	210 519	227 679	232 861	263 827	288 016	304 705	349 521	463 397

[1]Industry coverage is the same as in Tables 28, 30 and 33. [2]Total cost of fuel and electricity purchased by small establishments without detail.
— Nil.

Table 35. Canada, employment, salaries and wages in the mining industry,[1] 1967-74

	Unit	1967	1968	1969	1970	1971	1972	1973	1974
Metals									
Production and related workers	Number	48 262	49 238	46 023	51 102	50 121	46 257	47 984	50 886
Salaries and wages	$000	317 978	350 321	341 495	421 893	434 222	430 919	494 631	580 185
Annual average salary and wage	$	6 589	7 115	7 420	8 256	8 664	9 316	10 308	11 402
Administrative and office workers	Number	13 466	14 131	14 527	15 488	15 891	15 737	18 150	19 152
Salaries and wages	$000	111 405	124 451	137 756	158 653	178 640	189 669	238 454	282 348
Annual average salary and wage	$	8 273	8 807	9 483	10 244	11 242	12 052	13 138	14 732
Total metals									
Employees	Number	61 728	63 369	60 550	66 590	66 012	61 994	66 134	70 038
Salaries and wages	$000	429 383	474 772	479 251	580 546	612 862	620 588	733 085	862 533
Annual average salary and wage	$	6 956	7 492	7 915	8 718	9 284	10 011	11 085	12 315
Nonmetals									
Production and related workers	Number	15 049	15 458	15 933	16 245	16 155	15 911	16 344	17 767
Salaries and wages	$000	84 755	94 850	107 622	114 345	122 355	131 372	147 027	180 962
Annual average salary and wage	$	5 632	6 136	6 755	7 039	7 574	8 257	9 002	10 185
Administrative and office workers	Number	3 807	4 051	4 081	4 415	4 278	4 109	4 335	4 628
Salaries and wages	$000	28 397	32 836	34 980	39 533	40 222	43 030	47 092	57 243
Annual average salary and wage	$	7 459	8 106	8 571	8 954	9 402	10 472	10 863	12 369
Total nonmetals									
Employees	Number	18 856	19 509	20 014	20 660	20 433	20 020	20 667	22 395
Salaries and wages	$000	113 152	127 686	142 602	153 878	162 577	174 402	194 119	238 205
Annual average salary and wage	$	6 001	6 545	7 125	7 448	7 957	8 711	9 393	10 637
Fuels									
Production and related workers	Number	10 919	10 370	9 412	9 861	10 425	10 876	10 849	11 275
Salaries and wages	$000	62 756	64 832	64 591	77 846	90 324	104 214	110 220	133 392
Annual average salary and wage	$	5 747	6 252	6 863	7 894	8 664	9 582	10 160	11 831
Administrative and office workers	Number	11 175	11 668	12 112	12 983	13 540	14 432	13 793	15 022
Salaries and wages	$000	95 387	105 163	118 395	131 744	149 898	169 579	177 447	216 200
Annual average salary and wage	$	8 536	9 013	9 775	10 147	11 071	11 750	12 865	14 392
Total fuels									
Employees	Number	22 094	22 038	21 524	22 844	23 965	25 308	24 642	26 297
Salaries and wages	$000	158 143	169 995	182 986	209 590	240 222	273 793	287 667	349 592
Annual average salary and wage	$	7 158	7 714	8 502	9 175	10 024	10 818	11 674	13 294

Table 35. (concl'd)

	Unit	1967	1968	1969	1970	1971	1972	1973	1974
Total mining									
Production and related workers	Number	74 230	75 066	71 368	77 208	76 701	73 044	75 177	79 928
Salaries and wages	$000	465 489	510 003	513 708	614 084	646 901	666 505	751 878	894 538
Annual average salary and wage	$	6 271	6 794	7 198	7 954	8 434	9 125	10 003	11 192
Administrative and office workers	Number	28 448	29 850	30 720	32 886	33 709	34 278	36 278	38 802
Salaries and wages	$000	235 189	262 450	291 131	329 930	368 760	402 278	462 993	555 792
Annual average salary and wage	$	8 267	8 792	9 477	10 033	10 940	11 736	12 762	14 324
Total mining									
Employees	Number	102 678	104 916	102 088	110 094	110 410	107 322	111 455	118 730
Salaries and wages	$000	700 678	772 453	804 839	944 014	1 015 661	1 068 783	1 214 871	1 450 330
Annual average salary and wage	$	6 824	7 363	7 884	8 575	9 199	9 959	10 901	12 215

[1] According to the revised Standard Industrial Classification (1970). Does not include cement and lime manufacturing and clay products (domestic clays) manufacturing. These industries are included in Table 36 under "Nonmetallic mineral products industries." See Table 27 for detail of industries covered.

Table 36. Canada, employment salaries and wages in the mineral manufacturing industries, 1967-74

	Unit	1967	1968	1969	1970	1971	1972	1973	1974
Primary metal industries									
Production and related workers	Number	86 784	86 237	83 564	88 839	86 452	86 335	89 853	94 538
Salaries and wages	$000	541 970	570 183	583 498	680 779	714 600	781 209	897 353	1 052 519
Annual average salary and wage	$	6 245	6 612	6 983	7 663	8 266	9 049r	9 987	11 133
Administrative and office workers	Number	23 294	26 786	27 389	27 706	27 862	27 623	26 609	27 681
Salaries and wages	$000	185 800	233 273	255 548	277 728	303 113	327 598	340 547	403 151
Average annual salary and wage	$	7 976	8 709	9 330	10 024	10 879	11 860	12 798	14 564
Total primary metal industries									
Employees	Number	110 078	113 023	110 953	116 545	114 314	113 958	116 462	122 219
Salary and wages	$000	727 770	803 456	839 046	958 507	1 017 713	1 108 807	1 237 900	1 455 671
Annual average salary and wage	$	6 611	7 109	7 562	8 224	8 903	9 730	10 629	11 910
Nonmetallic mineral products industries									
Production and related workers	Number	37 467	37 796	38 107	36 045	38 035	39 159	41 502	42 884
Salaries and wages	$000	207 204	223 173	246 196	244 201	281 046	316 033	366 028	424 096
Annual average salary and wage	$	5 530r	5 905r	6 461	6 775	7 389	8 071	8 820	9 889
Administrative and office workers	Number	11 793	13 874	13 781	13 383	13 256	13 928	14 447	14 682
Salaries and wages	$000	79 464	102 869	111 568	117 163	124 085	142 193	156 085r	180 802
Annual average salary and wage	$	6 738	7 415	8 096	8 755	9 361	10 209	10 804r	12 314
Total nonmetallic mineral products									
Employees	Number	49 260	51 670	51 888	49 428	51 291	53 087	55 949	57 566
Salaries and wages	$000	286 668	326 042	357 764	361 364	405 131	458 226	522 113	604 898
Annual average salary and wage	$	5 820	6 310	6 895	7 311	7 899	8 632	9 332	10 507
Petroleum and coal products industries									
Production and related workers	Number	6 839	6 876	6 590	6 686	6 557	6 583	6 822	7 787
Salaries and wages	$000	52 462	56 703	61 217	64 745	68 215	75 735	84 537	105 398
Annual average salary and wage	$	7 671	8 247	9 289	9 684	10 403	11 505	12 392	13 535
Administrative and office workers	Number	3 264	8 755	9 043	8 961	8 960	8 826	9 265	9 648
Salaries and wages	$000	28 287	81 767	90 436	95 908	104 378	110 301	125 906	149 140
Annual average salary and wage	$	8 666	9 340	10 001	10 703	11 649	12 497	13 589	15 458
Total petroleum and coal products									
Employees	Number	10 103	15 631	15 633	15 647	15 517	15 409	16 087	17 435
Salaries and wages	$000	80 749	138 470	151 653	160 653	172 593	186 036	210 443	254 539
Annual average salary and wage	$	7 993	8 859	9 701	10 267	11 123	12 073	13 082	14 599

Table 36. (concl'd)

	Unit	1967	1968	1969	1970	1971	1972	1973	1974
Total mineral manufacturing industries									
Production and related workers	Number	131 090	130 909	128 261	131 570	131 044	132 077	138 177	145 209
Salaries and wages	$000	801 636	850 059	890 911	989 725	1 063 861	1 172 977	1 347 918	1 582 014
Annual average salary and wage	$	6 115	6 494	6 946	7 522	8 118	8 881	9 755	10 895
Administrative and office workers	Number	38 351	49 415	50 213	50 050	50 078	50 377	50 321	52 011
Salaries and wages	$000	293 551	417 909	457 552	490 799	531 576	580 092	622 538r	733 093
Annual average salary and wage	$	7 654	8 457	9 112	9 806	10 615	11 515	12 371r	14 095
Total mineral manufacturing industries									
Employees	Number	169 441	180 324	178 474	181 620	181 122	182 454	188 498	197 220
Salaries and wages	$000	1 095 187	1 267 968	1 348 463	1 480 524	1 595 437	1 753 069	1 970 456	2 315 107
Annual average salary and wage	$	6 464	7 032	7 556	8 151	8 809	9 608	10 454	11 739

Note: See Footnote Table 35. See Table 28 for detail of industries convered.
rRevised.

Table 37. Canada, number of wage earners, employed in the mining industry[1] (surface, underground and mill), 1971-74

	1971	1972	1973	1974
Metals				
Surface	14 316	13 171	15 060	16 229
Underground	24 907	22 177	20 336	21 045
Mill	10 898	10 909	12 588	13 612
Total	50 121	46 257	47 984	50 886
Nonmetals				
Surface	7 650	6 952	7 080	7 743
Underground	1 733	1 792	1 881	2 210
Mill	6 772	7 167	7 383	7 814
Total	16 155	15 911	16 344	17 767
Fuels				
Surface	5 798	7 576	7 820	8 443
Underground	4 627	3 300	3 029	2 832
Total	10 425	10 876	10 849	11 275
Total mining industry				
Surface	27 764	27 699	29 960	32 415
Underground	31 267	27 269	25 246	26 087
Mill	17 670	18 076	19 971	21 426
Total	76 701	73 044	75 177	79 928

[1]See Table 27 for coverage.

Table 38. Canada, labour costs in relation to tonnes mined, metal mines, 1972-74

Type of metal mine	Number of Wage Earners	Total Wages	Average Annual Wage	Tonnes of Ore Mined	Average Annual Tonnes Mined per Wage Earner	Wage Cost per Tonne Mined
		($000)	($)	(000 tonnes)	(tonnes)	($)
1974						
Auriferous quartz[1]	4 716	47 597	10 092	5 629	1 194	8.46
Copper-gold-silver	13 878	169 800	12 235	111 380	8 026	1.52
Nickel-copper	15 125	148 335	9 807	25 303	1 673	5.86
Silver-cobalt[2]	. .	. .	. .	. .	. .	. .
Silver-lead-zinc	4 940	52 702	10 668	14 189	2 872	3.71
Iron ore	9 560	131 199	13 723	107 105	11 203	1.22
Miscellaneous metals	2 667	30 552	11 455	15 008	5 627	2.04
Total	50 886	580 185	11 401	278 614	5 475	2.08
1973						
Auriferous quartz[1]	4 727	37 438	7 920	5 863	1 240	6.34
Copper-gold-silver	12 994	133 032	10 238	106 072	8 163	1.25
Nickel-copper	14 696	149 720	10 188	23 167	1 576	6.46
Silver-cobalt[2]	. .	. .	. .	. .	. .	. .
Silver-lead-zinc	4 489	44 082	9 820	15 362	3 422	2.87
Iron ore	8 521	104 030	12 209	108 622	12 748	0.96
Miscellaneous metals	2 557	26 329	10 297	15 687	6 135	1.68
Total	47 984	494 631	10 308	274 773	5 726	1.80
1972						
Auriferous quartz[1]	4 663	32 902	7 056	6 089	1 306	5.40
Copper-gold-silver	12 449	115 684	9 293	66 608	5 350	1.73
Nickel-copper	15 310	146 519	9 570	23 097	1 509	6.34
Silver-cobalt[2]	125	964	7 712	122	976	7.90
Silver-lead-zinc	4 391	38 490	8 766	14 154	3 223	2.71
Iron ore	6 693	70 695	10 563	83 232	12 435	0.84
Miscellaneous metals	2 626	25 664	9 773	12 668	4 824	2.02
Total	46 257	430 918	9 316	205 970	4 453	2.09

[1]Placer gold mines no longer surveyed. [2]Included with silver-lead-zinc mines.
. . Not available.

Table 39. Canada, man-hours paid, production and related workers, tonnes of ore mined and rock quarried, metal mines and nonmetallic mineral operations, 1968-74

	Unit	1968	1969	1970	1971	1972	1973	1974
Metal mines[1]								
Ore mined	million tonnes	186.9	172.0	213.0	211.4	205.9	274.7	278.7
Man-hours paid[2]	million	105.2	95.8	108.2	102.1	93.8	98.4	104.0
Man-hours paid per ton mined	number	0.56	0.56	0.51	0.48	0.46	0.36	0.37
Tons mined per man-hour paid	tonnes	1.78	1.80	1.97	2.07	2.20	2.79	2.68
Nonmetallic mineral operations[3]								
Ore mined and rock quarried	million tonnes	157.3	163.2	161.5	165.9	169.3	190.5	209.7
Man-hours paid[2]	million	25.9	28.4	28.6	27.5	27.4	28.6	30.5
Man-hours paid per tonne mined	number	0.16	0.17	0.18	0.17	0.16	0.15	0.15
Tons mined per man-hour paid	tonnes	6.07	5.75	5.65	6.03	6.18	6.66	6.88

[1]Excludes placer mining. [2]Man-hours paid for production and related workers only. [3]Excludes salt, cement, clay products, stone for cement and lime manufacture, and peat.

Table 40. Canada, basic wage rates per hour in metal mining industry on October 1, 1975 and 1976

	Gold Mines[1]		Iron Mines[2]		Other Metal Mines[3]	
	1975	1976^p	1975	1976^p	1975	1976^p
	($)					
Underground workers						
Cageman	5.69	6.24	. .	. .	5.27	5.94
Car dropper	. .	. .	. .	. .	5.42	. .
Dinkey-engine operator	. .	. .	. .	. .	5.55	6.03
Grizzly worker	. .	. .	. .	. .	5.55	5.83
Hoist operator	5.85	6.36	. .	. .	5.59	6.39
Labourer	5.38	. .	. .	. .	5.09	5.75
Mechanical shovel operator	5.46	. .	. .	. .	5.27	6.18
Miner, all-round	5.56	8.63	. .	. .	5.43	6.02
Miner's helper	5.57	. .	. .	. .	4.95	5.47
Timber and steel-prop setter	. .	. .	. .	. .	5.15	5.94
Track repairman	. .	. .	. .	. .	5.31	5.80
Open-pit workers						
Blaster	. .	. .	6.51	7.26	. .	. .
Bulldozer operator	. .	. .	6.19	7.26	. .	. .
Driller machine operator	. .	. .	6.77	7.32	. .	. .
Dumptruck driver	. .	. .	6.56	. .	. .	. .
Oiler and greaser	. .	. .	5.95	6.68	. .	. .
Shovel operator (power)	. .	. .	7.02	8.07	. .	. .
Surface and mill workers						
Bit-sharpener tender	. .	5.92	. .	. .	5.45	6.00
Blacksmith	. .	. .	. .	. .	6.22	7.26
Carpenter, maintenance	. .	. .	6.81	7.51	6.42	6.97
Crusher tender	5.70	6.13	6.36	7.02	5.41	6.03
Diesel mechanic	. .	. .	7.14	8.27	6.66	7.21
Electrical repairman	. .	. .	7.14	7.95	6.62	7.29
Filtering attendant	. .	. .	. .	. .	5.28	6.26
Flotation-cell tender	. .	. .	. .	. .	5.46	6.31
Grinder and classifier tender	. .	. .	6.62	7.16	5.36	6.30
Labourer	. .	. .	5.30	6.02	5.01	5.72
Leaching operator	. .	. .	. .	. .	. .	5.66
Maintenance machinist	. .	. .	7.24	7.94	6.51	7.31
Maintenance-man helper	5.23	. .	. .	. .	5.31	5.87
Millman[4]	. .	. .	. .	. .	. .	. .
Millwright	. .	. .	7.02	7.80	6.63	7.07
Pipefitter, maintenance	. .	. .	6.80	7.55	6.46	7.23
Truck driver, light and heavy	. .	. .	6.23	6.96	5.66	6.45
Welder, maintenance	. .	. .	7.01	7.74	6.51	7.16

[1]Figures from Quebec and Ontario only. [2]Figures from Newfoundland, Ontario, Quebec and British Columbia. [3]Figures from Quebec, Ontario and British Columbia. [4]Includes filtering attendant, grinder and classifier and leaching operator.
^{p}Preliminary; . . Not available.

Table 41. Canada, average weekly wages and hours worked, hourly-rated employees in mining, manufacturing and construction industries, 1969-76

	1969	1970	1971	1972	1973	1974	1975	1976[p]
Mining								
Average hours per week	41.4	41.0	40.4	40.3	40.9	40.4	40.0	40.3
Average weekly wage ($)	135.94	152.10	163.22	174.94	196.89	225.25	260.74	298.37
Metals								
Average hours per week	40.7	40.3	39.3	39.0	39.6	39.4	39.4	39.6
Average weekly wage ($)	137.68	154.68	164.27	174.69	195.89	222.80	260.33	296.66
Mineral fuels								
Average hours per week	41.9	42.0	41.4	41.0	41.0	40.6	39.7	40.6
Average weekly wage ($)	122.88	146.68	161.46	176.36	198.08	231.51	264.98	297.28
Nonmetals								
Average hours per week	41.9	41.3	41.4	41.3	41.3	41.1	40.1	40.5
Average weekly wage ($)	129.05	139.21	151.52	158.30	173.10	191.51	230.84	273.56
Manufacturing								
Average hours per week	40.0	40.0	40.3	40.4	39.6	38.9	38.6	38.7
Average weekly wage ($)	111.69	119.69	130.22	141.53	152.77	170.03	195.12	222.61
Construction								
Average hours per week	39.8	39.2	39.2	40.1	39.5	38.9	39.0	38.9
Average weekly wage ($)	146.90	165.04	186.20	206.43	223.86	251.08	293.96	337.39

[p] Preliminary.

Table 42. Canada, average weekly wages of hourly-rated employees in mining industry in current and 1961 dollars, 1969-76

	1969	1970	1971	1972	1973	1974	1975	1976ᵖ
Current dollars								
All mining	135.94	152.10	163.22	174.94	196.89	222.25	260.74	298.37
Metals	137.68	154.68	164.27	174.69	195.89	222.80	260.33	296.66
Gold	107.69	113.72	124.61	131.92	151.73	192.78	219.97	251.23
Mineral fuels	122.88	146.68	161.46	176.36	198.08	231.51	264.98	297.28
Coal	108.58	130.37	144.26	158.18	181.29	212.56	243.01	273.97
Nonmetals except fuel	129.05	139.21	151.52	158.30	173.10	191.51	230.84	273.56
1961 dollars								
All mining	108.32	117.27	122.35	125.14	130.91	133.24	141.09	150.23
Metals	109.71	119.26	123.14	124.96	130.25	133.57	140.87	149.23
Gold	85.81	87.68	93.41	94.36	100.88	115.58	119.03	126.50
Mineral fuels	97.91	113.09	121.03	126.15	131.70	138.79	143.38	149.68
Coal	86.52	100.52	108.14	113.15	120.54	127.43	131.49	137.95
Industrial minerals	102.83	107.33	113.58	113.23	115.09	114.81	124.91	137.74

ᵖPreliminary.

Table 43. Canada, industrial fatalities per thousand workers, by industry groups, 1974-76

	Fatalities (number)			Number of workers (000)			Rate per 1 000 workers		
	1974ʳ	1975	1976ᵖ	1974	1975	1976ᵖ	1974ʳ	1975	1976ᵖ
Agriculture	33	13	16	473	479	474	0.07	0.03	0.03
Forestry	85	71	58	82	72	72	1.04	0.99	0.81
Fishing	11	27	26	24	23	20	0.46	1.17	1.30
Mining[1]	203	158	143	126	132	146	1.61	1.20	0.98
Manufacturing	305	222	161	2 024	1 951	1 945	0.15	0.11	0.08
Construction	232	217	167	598	605	642	0.39	0.36	0.26
Transportation	254	216	197	790	806	834	0.32	0.27	0.24
Trade	119	74	52	1 575	1 633	1 658	0.08	0.05	0.03
Finance	7	3	7	446	460	501	0.02	0.07	0.01
Service	101	83	52	2 386	2 508	2 595	0.04	0.03	0.02
Public administration	63	84	47	613	639	685	0.10	0.13	0.07
Total	1 413	1 168	926	9 137	9 308	9 572	0.16	0.13	0.10

Note: See footnotes, Table 44.
[1]Includes: Fatalities resulting from occupational chest diseases such as silicosis, lung cancer, etc. In 1976, 63 (1975ʳ, 88) fatalities of this type were reported.
ᵖPreliminary; ʳRevised.

Table 44. Canada, industrial fatalities per thousand workers, by industry groups, 1966-76

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]
Agriculture	0.10	0.05	0.05	0.06	0.03	0.04	0.06	0.06[r]	0.07	0.03	0.03
Forestry	1.45	1.34	1.28	1.10	1.31	1.31	1.09[r]	1.25[r]	1.04	0.99	0.81
Fishing[1]	1.42	1.32	0.79	0.86	1.25	0.50	0.36[r]	0.60	0.46	1.17	1.30
Mining[2]	1.12	1.61	1.15	1.40	1.26	1.31	1.41[r]	1.50[r]	1.61	1.20	0.98
Manufacturing	0.13	0.11	0.10	0.11	0.10	0.10	0.14[r]	0.13[r]	0.15	0.11	0.08
Construction	0.59	0.47	0.46	0.49	0.41	0.46	0.42	0.41[r]	0.39	0.36	0.26
Transportation[3]	0.40	0.36	0.26	0.30	0.27	0.29	0.31	0.35[r]	0.32	0.27	0.24
Trade	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.06[r]	0.08	0.05	0.03
Finance[4]	0.00	0.02	0.00	0.01	0.01	0.01	0.02	0.02[r]	0.02	0.07	0.01
Service[5]	0.03	0.03	0.02	0.03	0.03	0.03	0.05	0.04[r]	0.04	0.03	0.02
Public administration	0.07	0.08	0.14	0.14	0.17[r]	0.13	0.12[r]	0.18[r]	0.10	0.13	0.07
Total	0.17	0.16	0.14	0.14	0.13	0.14	0.15	0.16[r]	0.16	0.13	0.10

[1]Includes trapping, hunting. [2]Includes quarrying and oil wells. [3]Includes storage, communication, electric power and water utilities. [4]Includes insurance and real estate. [5]Includes community, business and personal service.

[p]Preliminary; [r]Revised.

Table 45. Canada, number of strikes and lockouts, by industries, 1975-76

	1975			1976p		
	Strikes and Lockouts	Workers Involved	Duration in Man-days	Strikes and Lockouts	Workers Involved	Duration in Man-days
Agriculture	—	—	—	—	—	—
Forestry	11	1 900	44 390	4	784	36 320
Fishing and trapping	4	11 394	246 430	1	350	350
Mines	46	33 231	1 179 380	49	24 930	579 430
Manufacturing	523	150 117	5 339 850	457	166 542	4 493 260
Construction	122	58 873	984 920	76	135 668	2 856 370
Transportation and utilities	114	83 806	1 398 670	142	52 038	622 630
Trade	89	19 747	343 460	93	8 518	199 550
Finance, insurance & real estate	10	2 505	164 530	8	168	13 110
Service	164	60 608	752 530	147	148 840	1 298 490
Public administration	87	34 262	404 650	59	22 883	62 680
Other industries[1]	1	50 000	50 000	3	1 010 200[2]	1 447 700
All industries	1 171	506 443	10 908 810	1 039	1 570 921	11 609 890

[1]Includes the Common Front in Quebec. [2]1976 includes the National Day of Protest.
p Preliminary; — Nil.

Table 46. Canada, ore mined and rock quarried in the mining industry, 1972-74

	1972	1973	1974
		(tonnes)	
Metals			
Gold quartz	6 089 586	5 862 987	5 628 780
Copper-gold-silver	66 607 559	106 072 013	111 380 588
Silver-cobalt	122 301	. . .	. . .
Silver-lead-zinc	14 154 497	15 362 813	14 295 470
Nickel-copper	23 096 416	23 168 058	25 302 459
Iron	83 231 430	108 621 530	107 104 903
Miscellaneous metals	12 668 826	15 686 680	15 008 660
Total	205 970 615	274 774 081	278 720 860
Nonmetals			
Asbestos	71 830 794	80 568 423	85 541 458
Feldspar, nepheline syenite	622 838	622 382	647 616
Quartz (excluding sand)	1 202 343	1 411 465	1 273 666
Gypsum	7 295 684	7 619 183	6 916 832
Talc, soapstone	78 612	85 440	90 756
Rock salt	4 193 490	4 105 136	4 290 820
Other nonmetallics	15 566 812	16 522 875	22 432 148
Total	100 790 573	110 934 904	121 193 296
Structural materials			
Stone, all kinds quarried	72 758 506	83 709 736	92 833 055
Stone used to make cement	13 290 514	14 941 306	14 947 658
Stone used to make lime	2 920 292	3 190 799	3 391 122
Total	88 969 312	101 841 841	111 171 835
Total ore mined and rock quarried	395 730 500	487 550 826	511 085 991

. . . Included in silver-lead-zinc mines.

Table 47. Canada, ore mined and rock quarried in the mining industry, 1939-74

	Metals	Nonmetals[1]	Total
		(million tonnes)	
1939	32.5	14.9	47.4
1940	35.9	18.4	54.3
1941	39.0	19.5	58.5
1942	38.5	19.6	58.1
1943	35.1	18.7	53.8
1944	32.0	17.5	49.5
1945	28.3	18.6	46.9
1946	26.2	22.4	48.6
1947	30.2	27.5	57.7
1948	33.4	30.3	63.7
1949	39.2	29.8	69.0
1950	41.6	37.9	79.5
1951	44.2	39.7	83.9
1952	47.4	40.0	87.4
1953	49.3	42.8	92.1
1954	53.5	55.7	109.2
1955	62.7	57.6	120.3
1956	70.2	66.2	136.2
1957	76.4	74.5	150.9
1958	71.4	71.2	142.6
1959	89.9	82.2	172.1
1960	92.1	88.7	180.8
1961	90.1	96.7	186.8
1962	103.6	103.8	207.4
1963	112.7	120.4	233.1
1964	128.0	134.0	146.8
1965	151.0	146.5	297.5
1966	147.6	171.8	319.4
1967	169.1	177.5	346.6
1968	186.9	172.6	359.5
1969	172.0	178.8	350.8
1970	213.0	178.9	391.9
1971	211.4	185.7	397.1
1972	206.0	189.7	395.7
1973	274.8	212.8	487.6
1974	278.7	232.4	511.1

[1]Includes nonmetallic mineral mining and all stone quarried, including stone used to make cement and lime. Excludes coal. Coverage same as in Table 46.

Table 48. Canada, exploration and capital expenditures in the mining industry[1], by provinces and territories, 1974-76

		Capital						Repair						
		Construction												
		On-Property Exploration	On-Property Development	Structures	Total	Machinery and Equipment	Total Capital	Construction	Machinery and Equipment	Total Repair	Total Capital and Repair	Outside or General Exploration	Land and Mining Rights	Total all Expenditures
		($ million)												
Atlantic Provinces	1974	1.7	19.7	26.8	48.2	29.9	78.1	16.7	96.9	113.6	191.7	10.1	. . .	. . .
	1975	1.9	25.7	38.0	65.6	35.0	100.6	16.2	106.2	122.4	223.0	13.4	0.5	236.9
	1976p	1.3	19.7	30.4	51.4	43.6	95.0	7.2	128.0	135.2	230.2	13.0	0.2	243.4
Quebec	1974	6.3	59.4	126.6	192.3	68.5	260.8	10.6	138.5	149.1	409.9	21.4	2.6	433.9
	1975	4.1	73.0	164.0	241.1	101.4	342.5	11.9	142.6	154.5	497.0	25.0	. . .	. . .
	1976p	7.5	111.2	192.2	310.9	163.0	473.9	14.7	179.5	194.2	668.1	20.3	5.7	694.1
Ontario	1974	7.1	73.2	44.6	124.9	70.9	195.8	17.3	122.7	140.0	335.8	19.6	3.1	358.5
	1975	8.3	98.4	52.6	159.3	84.6	243.9	25.3	141.0	166.3	410.2	23.3	. . .	. . .
	1976p	10.3	117.1	70.7	198.1	112.2	310.3	26.9	183.0	209.9	520.2	23.2	. . .	. . .
Manitoba	1974	. . .	. . .	. . .	15.7	7.8	23.5	2.7	26.7	29.4	52.9	6.9	0.1	59.9
	1975	. . .	. . .	. . .	20.7	13.9	34.6	1.8	37.8	39.6	74.2	6.0	—	80.2
	1976p	. . .	. . .	. . .	21.2	8.4	29.6	2.2	31.3	33.5	63.1	5.4	. . .	. . .
Saskatchewan	1974	. . .	. . .	. . .	30.3	23.4	53.7	7.0	33.5	40.5	94.2	6.3	0.1	100.6
	1975	. . .	. . .	. . .	22.7	71.6	94.3	11.3	38.4	49.7	144.0	9.7	0.3	154.0
	1976p	. . .	. . .	. . .	10.8	56.1	66.9	3.2	41.9	45.1	112.0	11.8	0.4	124.2
Alberta	1974	. . .	. . .	. . .	18.7	20.7	39.4	0.4	9.2	9.6	49.0	4.1	1.2	54.3
	1975	. . .	. . .	. . .	18.3	33.4	51.7	2.3	15.8	18.1	69.8	3.5	0.4	73.7
	1976p	1.7	6.5	19.0	27.2	65.4	92.6	5.3	23.8	29.1	121.7	4.3	1.4	127.4
British Columbia	1974	3.8	37.9	31.3	73.0	54.1	127.1	12.8	106.7	119.5	246.6	22.5	1.0	270.1
	1975	4.7	30.6	19.8	55.1	62.0	117.1	10.8	124.3	135.1	252.2	24.5	2.1	278.8
	1976p	7.9	59.1	44.1	111.1	55.4	166.5	10.9	132.9	143.8	310.3	23.6	4.5	338.4
Yukon and Northwest Territories	1974	2.2	13.0	7.3	22.5	8.3	30.8	4.3	16.2	20.5	51.3	19.9	. . .	. . .
	1975	2.8	11.3	15.5	29.6	23.0	52.6	7.9	24.9	32.8	85.4	23.7	0.4	109.5
	1976p	4.1	15.4	9.7	29.2	16.2	45.4	11.3	29.1	40.4	85.8	25.5	0.3	111.6
Canada	1974	25.2	228.6	271.8	525.6	283.6	809.2	71.8	550.4	622.2	1 431.4	110.8	20.2	1 562.4
	1975	25.7	274.3	312.4	612.4	424.9	1 037.3	87.5	631.0	718.5	1 755.8	129.1	12.5	1 897.4
	1976p	36.5	351.4	372.0	759.9	520.3	1 280.2	81.7	749.5	831.2	2 111.4	127.1	13.7	2 252.2

[1]Excludes the petroleum and natural gas industries, and the smelting and refining industries.
p Preliminary; — Nil; . . . Confidential, included in Canada Total.

Table 49. Canada, exploration and capital expenditures[1] in the mining industry by type of mining, 1974-76

		Capital						Repair						
		Construction												
		On-Property Exploration	On-Property Development	Structures	Total	Machinery and Equipment	Total Capital	Construction	Machinery and Equipment	Total Repair	Total Capital and Repair	Outside or General Exploration	Land and Mining Rights	Total all Expenditures
		($ million)												
Metal mining														
Gold	1974	1.9	19.4	3.2	24.5	5.9	30.4	1.2	8.5	9.7	40.1	1.9	0.3	42.3
	1975	1.7	17.3	1.7	20.7	5.3	26.0	0.8	10.9	11.7	37.7	1.6	—	39.3
	1976p	1.7	9.4	6.2	17.3	4.5	21.8	0.7	11.4	12.1	33.9	(2)	—	(3)
Copper-gold -silver	1974	5.0	51.0	41.7	97.7	66.7	164.4	14.7	108.7	123.4	287.8	3.3	—	291.1
	1975	6.4	54.1	48.7	109.2	51.8	161.0	10.3	125.1	135.4	296.4	5.3	0.7	302.4
	1976p	6.6	73.3	49.4	129.3	69.6	198.9	12.6	134.0	146.6	345.5	4.4	0.2	350.1
Silver-lead -zinc	1974	3.2	17.8	17.9	38.9	13.8	52.7	5.6	19.3	24.9	77.6	3.8	—	81.4
	1975	4.0	24.9	26.4	55.3	29.3	84.6	7.2	23.7	30.9	115.5	3.5	—	119.0
	1976p	4.4	34.1	16.7	55.2	22.7	77.9	10.9	36.4	47.3	125.2	2.9	(3)	(3)
Iron[2]	1974	(3)	(3)	(3)	159.0	40.7	199.7	21.5	171.9	193.4	393.1	1.8	0.1	395.0
	1975	(3)	(3)	(3)	225.8	83.8	309.6	20.5	191.3	211.8	521.4	1.5	—	522.9
	1976p	(2)	(2)	(2)	277.4	149.1	426.5	14.2	226.0	240.2	666.7	1.0	—	667.7
Other metal mining	1974	(3)	(3)	(3)	85.6	29.5	115.1	15.7	74.9	90.6	205.7	8.0	—	213.7
	1975	(3)	(3)	(3)	86.1	43.0	129.1	24.7	95.4	120.1	249.2	9.9	(4)	(4)
	1976p	11.5	157.0	219.9	111.0	58.5	169.5	23.3	114.5	137.8	307.3	14.2	(3)	(3)
Total metal mining[3]	1974	20.0	172.2	213.4	405.7	156.6	562.3	58.7	383.3	442.0	1 004.3	18.8	(4)	(4)
	1975	21.3	217.2	258.6	497.1	213.2	710.3	63.5	446.4	509.9	1 220.2	21.8	(4)	(4)
	1976p	24.2	273.8	292.2	590.2	304.4	894.6	61.7	522.3	584.0	1 478.6	22.5	1.5	1 502.6
Nonmetal mining														
Asbestos	1974	0.4	27.4	17.6	45.4	28.9	74.3	2.4	50.7	53.1	127.4	0.2	(4)	(4)
	1975	0.5	28.8	13.2	42.5	19.3	61.8	4.1	46.0	50.1	111.9	0.1	(4)	(4)
	1976p	(6)	43.1	22.8	65.9	29.0	94.9	5.9	69.8	75.7	170.6	0.2	(5)	(5)
Other non-metal mining	1974	2.1	28.2	40.3	70.6	96.8	167.4	10.7	116.3	127.0	294.4	2.7	5.1	302.2
	1975	2.6	27.6	40.1	70.3	190.3	260.6	19.7	138.3	158.0	418.6	7.8	1.3	427.7
	1976p	(6)	39.4	55.9	95.3	186.0	281.3	14.1	157.3	171.4	452.7	8.8	(5)	(5)

Table 49. (concl'd)

		Capital						Repair						
		Construction												
		On-Property Exploration	On-Property Development	Structures	Total	Machinery and Equipment	Total Capital	Construction	Machinery and Equipment	Total Repair	Total Capital and Repair	Outside or General Exploration	Land and Mining Rights	Total all Expenditures
		($ million)												
Total non-metal mining	1974	2.5	55.6	57.9	116.0	125.7	241.7	13.1	167.0	180.1	421.8	2.9	(4)	(4)
	1975	3.1	56.4	53.3	112.8	209.6	322.4	23.8	184.3	208.1	530.5	7.9	(4)	(4)
	1976[p]	9.1	73.4	78.7	161.2	215.0	376.2	20.0	227.1	247.1	623.3	9.0	6.8	639.1
Metal and non-metal mining exploration	1974	2.7	0.8	0.4	3.9	1.3	5.2	—	0.1	0.1	5.3	89.1	4.9	99.3
	1975	1.3	0.7	0.5	2.5	2.1	4.6	0.2	0.3	0.5	5.1	99.4	3.3	107.8
	1976[p]	3.2	4.2	1.1	8.5	0.9	9.4	—	0.1	0.1	9.5	95.6	5.4	110.5
Total mining	1974	25.2	228.6	271.8	525.6	283.6	809.2	71.8	550.4	622.2	1 431.4	110.8	20.2	1 562.4
	1975	25.7	274.3	312.4	612.4	424.9	1 037.3	87.5	631.0	718.5	1 755.8	129.1	12.5	1 897.4
	1976[p]	36.5	351.4	372.0	759.9	520.3	1 280.2	81.7	749.5	831.2	2 111.4	127.1	13.7	2 252.2

[1]Excludes expenditures in the petroleum and natural gas industries.
Note: (2) Confidential, included in Other Metal Mining. (3) Confidential, included in Total Metal Mining. (4) Confidential, included in Total Mining. (5) Confidential, included in Total Nonmetal Mining. (6) Confidential, included with On-Property Development.
[p]Preliminary; — Nil.

Table 50. Canada, diamond drilling in the mining industry, by mining companies with own equipment and by drilling contractors, 1973-74

		1973			1974		
		Exploration	Other	Total	Exploration	Other	Total
		(metres)					
Metal mining							
Gold quartz	Own equipment	13 661	8 880	22 541	21 024	10 069	31 093
	Contractors	215 644	5 523	221 167	212 800	6 355	219 155
	Total	229 305	14 403	243 708	233 824	16 424	250 248
Copper-gold-silver	Own equipment	43 411	16 345	59 756	90 214	—	90 214
	Contractors	313 023	17 285	330 308	362 582	13 445	376 027
	Total	356 434	33 630	390 064	452 796	13 445	466 241
Nickel-copper	Own equipment	244 847	7 087	251 934	228 591	—	228 591
	Contractors	51 739	19 397	71 136	130 732	—	130 732
	Total	296 586	26 484	323 070	359 323	—	359 323
Silver-lead-zinc and silver cobalt	Own equipment	19 414	44 850	64 264	17 994	15 893	33 887
	Contractors	106 628	15 054	121 682	158 268	5 085	163 353
	Total	126 042	59 904	185 946	176 262	20 978	197 240
Molybdenum	Own equipment	(1)	(1)	(1)	(1)	(1)	(1)
	Contractors	(1)	(1)	(1)	(1)	(1)	(1)
Iron mines	Own equipment	—	—	—	—	—	—
	Contractors	16 851	1 187	18 038	28 709	—	28 709
	Total	16 851	1 187	18 038	28 709	—	28 709
Miscellaneous metal mining	Own equipment	—	—	—	—	28 309	28 309
	Contractors	39 014	678	39 692	26 466	—	26 466
	Total	39 014	678	39 692	26 466	28 309	54 775
Total metal mining	Own equipment	321 333	77 162	398 495	357 823	54 271	412 094
	Contractors	742 899	59 124	802 023	919 557	24 885	944 442
	Total	1 064 232	136 286	1 200 518	1 277 380	79 156	1 356 536

Table 50. (concl'd)

		1973			1974		
		Exploration	Other	Total	Exploration	Other	Total
		(metres)					
Nonmetal mining							
Asbestos	Own equipment	11 999	–	11 999	35 626	–	35 626
	Contractors	9 444	–	9 444	21 581	–	21 581
	Total	21 443	–	21 443	57 207	–	57 207
Feldspar and quartz	Own equipment	–	–	–	–	–	–
	Contractors	2 177	–	2 177	2 563	–	2 563
	Total	2 177	–	2 177	2 563	–	2 563
Gypsum	Own equipment				–	–	–
	Contractors	(2)	(2)	(2)	1 513	–	1 513
	Total				1 513	–	1 513
Salt	Own equipment	291	–	291	–	–	–
	Contractors	–	–	–	–	–	–
	Total	291	–	291	–	–	–
Miscellaneous nonmetal mining	Own equipment	2 559	–	2 559	1 675	–	1 675
	Contractors	3 854	–	3 854	2 256	–	2 256
	Total	6 413	–	6 413	3 931	–	3 931
Total nonmetal mining	Own equipment	14 849	–	14 849	37 301	–	37 301
	Contractors	15 475	–	15 475	27 913	–	27 913
	Total	30 324	–	30 324	65 214	–	65 214
Total mining industry	Own equipment	336 182	77 162	413 344	395 124	54 271	449 395
	Contractors	758 374	59 124	817 498	947 470	24 885	972 355
	Total	1 094 556	136 286	1 230 842	1 342 594	79 156	1 421 750

Note: (1) Confidential, included in "Miscellaneous metal mining". (2) Confidential, included in "Miscellaneous nonmetal mining".
– Nil.

Table 51. Canada, total diamond drilling, metal deposits, 1961-74

	Gold-quartz deposits	Copper-gold-silver and nickel-copper deposits	Silver-lead-zinc and silver-cobalt deposits	Other metal bearing deposits[1]	Total metal deposits
			(metres)		
1961	595 180	1 128 090	255 100	221 079	2 199 449
1962	902 288	1 025 048	350 180	358 678	2 636 194
1963	529 958	977 257	288 204	148 703	1 944 122
1964	458 933	709 588	401 099	104 738	1 674 358
1965	440 020	779 536	331 294	275 917	1 826 767
1966	442 447	729 148	292 223	164 253	1 628 071
1967	391 347	947 955	230 182	120 350	1 689 834
1968	375 263	935 716	198 038	56 780	1 565 797
1969	274 410	923 452	197 670	109 592	1 505 124
1970	214 717	1 132 915	375 019	99 373	1 822 024
1971	193 291	1 089 103	308 798	83 851	1 675 043
1972	229 771	967 640	224 495	50 225	1 472 131
1973	243 708	713 134	185 946	57 730	1 200 518
1974	250 248	825 564	197 240	83 484	1 356 536

Note: Nonproducing companies not included 1964.
[1]Includes iron, titanium, uranium, molybdenum and other metal deposits.

Table 52. Canada, exploration diamond drilling, metal deposits, 1961-74

	Mining companies with own personnel and equipment	Diamond drill contractors	Total
		(metres)	
1961	302 696	1 337 173	1 639 869
1962	167 214	1 748 022	1 915 236
1963	361 180	1 169 292	1 530 472
1964	143 013	1 072 985	1 215 998
1965	209 002	1 176 996	1 385 998
1966	163 379	1 044 860	1 208 239
1967	93 164	1 123 137	1 216 301
1968	159 341	990 690	1 150 031
1969	135 311	1 072 328	1 207 639
1970	62 147	1 228 061	1 290 208
1971	86 838	1 053 330	1 140 168
1972	249 845	825 859	1 075 704
1973	321 333	742 899	1 064 232
1974	357 823	919 557	1 277 380

Note: Nonproducing companies not included since 1964. See footnote to Table 53.

Table 53. Canada, diamond drilling, other than for exploration, metal deposits, 1961-74

	Mining companies with own personnel and equipment	Diamond drill contractors	Total
		(metres)	
1961	384 432	175 149	559 581
1962	528 700	192 259	720 959
1963	388 228	25 422	413 650
1964	385 765	72 594	458 359
1965	393 947	46 822	440 769
1966	227 968	191 863	419 831
1967	186 755	287 071	473 536
1968	122 851	292 914	415 765
1969	87 552	209 933	297 485
1970	290 363	241 453	531 816
1971	295 966	238 940	534 876
1972	304 523	91 903	396 426
1973	77 162	59 124	136 286
1974	54 271	24 885	79 156

Note: Nonproducing companies not included since 1964. Total footage drilled shown in Tables 52 and 53 equals the total footage drilled reported in Table 51.

Table 54. Canada, total contract diamond drilling operations,[1] 1962-74

	Metres drilled	Income from drilling	Average number of employees	Total salaries and wages
		($ million)		($ million)
1962	1 691 558	17.9	1 926	8.0
1963	1 738 020	20.1	2 201	9.0
1964	1 974 828	23.7	2 401	11.2
1965	2 256 993	30.7	2 776	14.1
1966	2 275 717	33.7	2 887	15.1
1967	2 120 575	31.3	2 669	14.9
1968	2 321 105	38.7	2 985	18.8
1969	2 367 368	44.8	3 109	21.3
1970	2 324 859	53.2	3 207	24.3
1971	1 888 453	38.1	2 514	18.9
1972	1 578 218	35.9	2 083	16.6
1973	1 596 967	39.1	2 123	18.7
1974	1 689 598	51.6	2 317	22.6

[1]Includes contract diamond drilling in mining and in other industries.

Table 55. Canada, contract drilling for oil and natural gas, 1963-74

	Metres drilled				Gross income from drilling	Number of employees	Total salaries and wages
	Rotary	Cable	Diamond	Total	($ million)		($ million)
1963	4 201 091	110 331	—	4 311 422	75.9	4 179	22.9
1964	4 512 190	70 020	1 898	4 584 108	81.9	4 158	25.2
1965	4 875 969	103 737	—	4 979 706	100.2	4 648	31.7
1966	4 082 617	64 039	—	4 146 656	95.8	4 428	33.9
1967	3 876 269	51 217	—	3 927 486	94.7	4 249	32.9
1968	4 054 073	70 239	—	4 124 312	109.5	4 434	36.9
1969	3 974 024	85 442	—	4 059 466	115.5	4 821	39.5
1970	3 505 457	50 304	—	3 555 761	112.6	4 267	37.9
1971	3 551 027	41 002	—	3 592 029	109.5	4 093	38.0
1972	4 332 240	42 362	—	4 374 602	154.6	4 817	53.5
1973	4 881 533	24 045	—	4 905 578	213.3	5 680	75.5
1974	4 380 546	17 372	—	4 397 918	206.1	5 054	74.4

— Nil.

Table 56. Canada, crude minerals transported by Canadian railways, 1974-75

	1974	1975		1974	1975
	(thousand tonnes)			(thousand tonnes)	
Metallic minerals					
Alumina and bauxite	2 771	2 379	Salt, rock	996	850
Copper ores and concentrates	2 762	2 255	Salt, nes	262	253
Iron ores and concentrates	50 816	49 004	Sand, industrial	1 559	1 192
Iron pyrite	40	21	Sand, nes	914	354
Lead ores and concentrates	620	667	Silica	36	41
Lead-zinc ores and concentrates	68	88	Sodium carbonate	540	328
Manganese ores	36	11	Sodium sulphate	706	526
Nickel-copper ores and			Stone, building, rough	122	19
concentrates	3 461	4 086	Stone, nes	1 585	1 175
Nickel ores and concentrates	1 564	1 813	Sulphur, liquid	1 653	1 206
Zinc ores and concentrates	2 238	2 123	Sulphur, nes	3 408	2 883
Metallic ores and concentrates, nes	133	84	Nonmetallic minerals, nes	376	195
Total metallic minerals	64 509	62 531	Total nonmetallic minerals	35 593	28 825
			Mineral fuels		
Nonmetallic minerals			Coal, anthracite	337	253
Abrasives, natural	127	85	Coal, bituminous	14 083	18 180
Asbestos	1 111	776	Coal, lignite	390	423
Barite	66	52	Coal, nes	35	18
Clay	644	522	Natural gas and other crude		
Gravel	1 262	934	bituminous substances	7	9
Gypsum	4 033	3 638	Petroleum, crude	346	382
Limestone, agricultural	150	185	Total mineral fuels	15 198	19 265
Limestone, industrial	463	232			
Limestone, nes	4 046	3 514	Total crude minerals	115 300	110 621
Nepheline syenite	11	1	Total all revenue freight moved by		
Phosphate rock	2 423	2 548	Canadian railways	246 314	225 981
Potash (KCl)	9 080	7 300	Per cent crude minerals of total		
Refractory materials, nes	20	16	revenue freight	46.8	49.0

nes Not elsewhere specified.

Table 57. Canada, crude minerals transported by Canadian railways, 1966-75

Year	Total Revenue Freight	Total Crude Minerals	Crude Minerals as % of Total Revenue Freight
	(million tonnes)		
1966	194.5	80.6	41.5
1967	190.0	81.2	42.7
1968	195.4	86.7	44.4
1969	189.0	81.9	43.4
1970	211.6	97.5	46.1
1971	214.5	95.6	44.6
1972	215.8	89.4	41.4
1973	241.2	113.1	46.9
1974	246.3	115.3	46.8
1975	226.0	110.6	49.0

Table 58. Canada, fabricated mineral products transported by Canadian railways, 1974-75

	1974	1975
	(thousand tonnes)	
Metallic mineral products		
Ferrous mineral products		
Ferroalloys	208	139
Pig iron	200	87
Ingots, blooms, billets, slabs of iron and Steel	552	294
Other primary iron and steel	107	58
Castings and forgings, iron and steel	296	254
Bars and rods, steel	1 156	694
Plates, steel	610	515
Sheet and strip, steel	1 646	1 208
Structural shapes and sheet piling, iron and steel	636	419
Rails and railway track material	217	162
Pipes and tubes, iron and steel	699	757
Wire, iron or steel	60	41
Iron and steel scrap	2 140	1 770
Slags, drosses, etc.	251	189
Total ferrous mineral products	8 778	6 587
Nonferrous mineral products		
Aluminum paste, powder, pigs, ingots, shot	156	130
Aluminum and aluminum alloy fabricated material, nes	277	224
Copper matte and precipitates	1	6
Copper and alloys, in primary forms	526	387
Copper and alloys, nes	156	197
Lead and alloys	127	145
Nickel and nickel-copper matte	156	150
Nickel and alloys	82	52
Zinc and alloys	420	340
Other nonferrous base metals and alloys	19	11
Nonferrous metal scrap	215	178
Total nonferrous mineral products	2 135	1 820
Total metallic mineral products	10 913	8 407
Nonmetallic mineral products		
Natural stone basic products, chiefly structural	271	206
Bricks and tiles, clay	102	57
Fire brick and similar shapes	237	154
Dolomite and magnesite, calcined	62	97
Refractories, nes	63	44
Glass basic products	245	115
Asbestos and asbestos-cement basic products	19	22
Portland cement, standard	1 787	1 730
Concrete pipe	89	70
Cement and concrete basic products, nes	294	250
Plaster	50	32
Gypsum wallboard and sheathing	106	81
Gypsum basic products, nes	1	1
Lime, hydrated and quick	636	392
Nonmetallic mineral basic products, nes	633	739
Fertilizers and fertilizer materials nes	1 959	1 696
Total nonmetallic mineral products	6 554	5 686
Mineral fuel products		
Gasoline	2 025	1 942
Aviation turbine fuel	107	78
Diesel fuel	3 726	3 524
Kerosene	17	51
Fuel oil, nes	911	840
Lubricating oils and greases	446	355
Petroleum coke	390	431
Coke, nes	1 393	942
Refined and manufactured gases, fuel type	3 369	3 248
Asphalts and road oils	295	273
Bituminous pressed or molded fabricated materials	2	1
Other petroleum and coal products	781	869
Total mineral fuel products	13 462	12 554
Total fabricated mineral products	30 929	26 647
Total revenue freight moved by Canadian railways	246 314	225 981
Fabricated mineral products as a percentage of total revenue freight	12.6	11.8

nes Not elsewhere specified.

Table 59. Canada, crude and fabricated minerals transported through the St. Lawrence Seaway, 1975-76

	Montreal-Lake Ontario Section		Welland Canal Section	
	1975	1976	1975	1976
	(tonnes)			
Crude minerals				
Bituminous coal	398 575	346 001	7 700 819	6 743 696
Iron ore	13 159 321	18 629 321	14 940 372	19 549 492
Aluminum ores and concentrates	26 393	47 484	26 393	47 484
Clay and bentonite	157 802	234 602	172 852	250 931
Gravel and sand	12 688	27 778	269 173	294 386
Stone, ground or crushed	66 073	51 710	1 068 294	993 733
Stone, rough	3 973	3 243	3 938	3 243
Petroleum, crude	171 639	—	—	—
Salt	779 557	752 354	1 356 107	1 507 482
Phosphate rock	62 743	36 246	—	—
Sulphur	31 576	43 741	31 576	43 741
Other crude minerals	827 346	712 110	530 866	479 448
Total crude minerals	15 697 686	20 884 590	26 100 390	29 913 636
Fabricated mineral products				
Coke	832 835	1 620 382	802 834	1 746 942
Gasoline	202 224	175 847	155 078	211 048
Fuel oil	1 770 019	1 360 776	1 032 553	725 972
Lubricating oils and greases	140 041	182 954	126 482	174 999
Other petroleum products	120 608	228 779	78 576	50 913
Tar, pitch and creosote	32 186	31 290	58 341	43 868
Pig iron	123 640	124 920	111 620	112 051
Iron and steel: bars, rods, slabs	544 602	266 256	507 603	218 823
Iron and steel: nails, wire	25 054	50 498	23 500	42 050
Iron and steel: other manufactured products	1 666 631	2 709 490	1 481 838	2 413 010
Scrap iron and steel	599 269	429 759	559 475	415 016
Cement	13 950	36	191 465	165 553
Total fabricated minerals	6 071 059	7 180 987	5 129 365	6 320 245
Total crude and fabricated minerals	21 768 745	28 065 577	31 229 755	36 233 881
Grand total, all products	43 554 304	49 348 441	53 386 938	58 368 445
Crude and fabricated minerals as a per cent of total	50.0	56.9	58.5	62.1

— Nil.

Table 60. Canada, crude minerals loaded and unloaded in coastwise shipping, 1975

	Loaded				Unloaded			
	Atlantic	Great Lakes	Pacific	Total	Atlantic	Great Lakes	Pacific	Total
	(tonnes)							
Metallic minerals								
Copper ore and concentrates	27 049	—	—	27 049	27 049	—	—	27 049
Iron ore and concentrates	3 283 945	2 405 797	—	5 689 742	1 030 455	4 659 287	—	5 689 742
Manganese ore	65 453	—	—	65 453	62 243	3 210	—	65 453
Titanium ore	2 337 344	—	—	2 337 344	2 337 344	—	—	2 337 344
Zinc ore and concentrates	10 113	4 857	—	14 970	14 970	—	—	14 970
Ores and concentrates, nes	113	—	—	113	68	45	—	113
Iron and steel scrap	8 884	—	1 369	10 253	8 884	—	1 369	10 253
Nonferrous metal scrap	139	—	—	139	139	—	—	139
Slag, drosses, residues	—	—	—	—	—	—	—	—
Total metals	5 733 040	2 410 654	1 369	8 145 063	3 481 152	4 662 542	1 369	8 145 063
Nonmetallic minerals								
Asbestos	—	—	—	—	—	—	—	—
Barite	952	—	—	952	952	—	—	952
Clays, nes	1 412	—	—	1 412	1 412	—	—	1 412
Dolomite	—	18 170	—	18 170	18 170	—	—	18 170
Fluorspar	—	—	—	—	—	—	—	—
Gypsum	636 804	—	—	636 804	528 305	108 499	—	636 804
Limestone	7 102	2 319 278	303 433	2 629 813	7 102	2 319 278	303 433	2 629 813
Potash (KCl)	—	—	—	—	—	—	—	—
Salt	181 126	883 907	31 469	1 096 502	634 744	430 289	31 469	1 096 502
Sand and gravel	1 114	12	1 845 392	1 846 518	1 092	35	1 845 391	1 846 518
Stone, crushed	—	—	—	—	—	—	—	—
Stone, crude, nes	305	339 417	33 416	373 138	26 894	312 829	33 415	373 138
Sulphur	—	—	7 200	7 200	—	—	7 200	7 200
Crude nonmetallic minerals, nes	394		1 988	2 382	394		1 988	2 382
Total nonmetals	829 209	3 560 784	2 222 898	6 612 891	1 219 065	3 170 930	2 222 896	6 612 891
Mineral fuels								
Coal, bituminous	213 607	549 285	165 721	928 613	235 621	692 992	—	928 613
Total crude minerals	6 775 856	6 520 723	2 389 988	15 686 567	4 935 838	8 526 464	2 224 265	15 686 567
Grand total, all commodities	21 208 033	23 449 167	9 715 460	54 372 660	28 817 904	16 023 307	9 531 449	54 372 660
Crude minerals as a per cent of all commodities	32.0	27.8	24.6	28.9	17.1	53.2	23.3	28.9

— Nil; nes Not elsewhere specified.

Table 61. Canada, crude minerals loaded and unloaded at Canadian ports in international shipping trade, 1974-75

	1974		1975	
	Loaded	Unloaded	Loaded	Unloaded
	(tonnes)			
Metallic minerals				
Alumina, bauxite ore	—	3 531 927	23 584	3 011 798
Copper ores and concentrates	971 417	62 168	694 818	—
Iron ore and concentrates	36 910 485	3 099 952	36 212 648	5 244 036
Lead ore and concentrates	138 229	—	94 145	—
Manganese ore	35 964	288 230	14 333	169 277
Nickel-copper ore and concentrates	85 719	5 371	59 696	23 468
Titanium ore	680 517	2 438	328 931	—
Zinc ore and concentrates	1 191 930	—	971 890	—
Ores and concentrates, nes	50 893	74 587	52 365	—
Iron and steel scrap	39 257	1 975	178 592	420
Nonferrous metal scrap	2 443	508	8 350	282
Slags, drosses, residues	709 344	35 278	671 837	9 049
Total metals	40 816 198	7 102 434	39 311 189	8 458 330
Nonmetallic minerals				
Asbestos	529 159	3 196	396 990	5 569
Barite	31 113	—	—	—
Bentonite	18	183 288	90	136 332
China clay	—	30 368	14	41 285
Clays, nes	828	46 020	58	55 449
Dolomite	1 270 682	—	971 156	—
Fluorspar	28 137	191 122	31 539	194 932
Gypsum	5 183 404	58 150	3 813 138	52 721
Limestone	880 056	2 660 466	999 417	3 135 812
Phosphate rock	—	1 324 475	—	1 411 899
Potash (KCl)	1 762 223	—	1 744 469	—
Salt	1 013 085	823 432	870 696	1 046 516
Sand and gravel	90 174	1 277 211	13 361	1 392 582
Stone, crushed	—	—	—	—
Stone, crude, nes	71 907	17 207	76 993	15 127
Sulphur	2 231 822	21 424	1 838 373	8 232
Crude, nonmetallic minerals, nes	92 465	11 846	43 735	35 228
Total nonmetals	13 185 073	6 648 205	10 800 029	7 531 684
Mineral fuels				
Coal, bituminous	8 498 778	11 975 071	10 649 700	15 384 838
Coal, nes	—	294 749	78 565	348 003
Natural gas	—	—	—	—
Petroleum, crude	1 593 094	19 193 096	1 130 327	19 834 275
Total fuels	10 091 872	31 462 916	11 858 592	35 567 116
Total crude minerals	64 093 143	45 213 555	61 969 810	51 557 130
Total, all commodities	106 110 095	60 718 070	102 444 469	63 776 026
Crude minerals as per cent of total commodities	60.4	74.5	60.5	80.8

— Nil; nes Not elsewhere specified.

Table 62. Canada, fabricated mineral products loaded and unloaded at Canadian ports in international shipping trade, 1974-75

	1974		1975	
	Loaded	Unloaded	Loaded	Unloaded
	(tonnes)			
Metallic products				
Aluminum	289 053	3 593	215 332	1 617
Copper and alloys	43 055	7 734	66 208	3 791
Ferroalloys	11 072	67 961	2 015	15 294
Iron and steel, primary	169 776	61 200	8 597	65 554
Iron, pig	408 124	—	327 852	23
Iron and steel, other				
bars and rods	19 567	244 446	10 712	178 380
castings and forgings	3 344	13 085	27 416	15 315
pipe and tubes	35 130	75 882	57 628	55 606
plate and sheet	139 213	683 949	149 802	242 064
rails and track material	36 749	39 387	86 387	28 968
structural shapes	49 523	536 030	53 406	165 636
wire	3 780	32 402	2 322	11 617
Lead and alloys	12 042	4 218	49 352	—
Nickel and alloys	15 341	14 094	1 686	16 040
Zinc and alloys	31 907	730	59 323	117
Nonferrous metals, nes	25 831	9 356	14 779	5 006
Metal fabricated basic products	14 521	38 752	23 743	15 958
Total metals	1 308 028	1 832 819	1 156 560	820 986
Nonmetallic products				
Asbestos basic products	5 893	2 228	2 145	443
Building brick, clay	81	1 621	—	—
Bricks and tiles, nes	12 224	15 242	11 149	11 479
Cement	1 199 977	107 963	999 850	91 908
Cement basic products	203	547	669	1 462
Drain tiles and pipes	194	107	9	58
Glass basic products	9 960	21 287	6 921	8 440
Lime	3 173	127	2 420	45
Nonmetallic mineral basic products	2 586	5 276	4 433	4 692
Fertilizers, nes	251 405	75 935	115 555	137 707
Total nonmetals	1 485 696	230 333	1 143 151	256 234
Mineral fuel products				
Asphalts, road oils	37 596	175	626	13 252
Coal tar, pitch	6 408	64 852	7 047	71 819
Coke	311 743	822 471	300 334	656 420
Fuel oil	5 078 811	3 183 622	3 921 851	1 121 032
Gasoline	131 891	4 983	582 154	22 255
Lubricating oils and greases	1 730	53 649	468	74 340
Petroleum and coal products, nes	679 402	39 368	382 445	33 886
Total fuels	6 247 581	4 169 120	5 194 925	1 993 004
Total fabricated mineral products	9 041 305	6 232 272	7 494 636	3 070 224
Grand total, all commodities	106 110 095	60 718 070	102 444 469	63 776 026
Fabricated mineral products as a per cent of total commodities	8.5	10.3	7.3	4.8

— Nil; nes Not elsewhere specified.

Table 63. Canada, financial statistics of corporations in the mining industry[1]

	Corporations		Assets	
	(Number)	(%)	($ million)	(%)
Metal mines				
Reporting corporations				
50 per cent and over non-resident	50	22.0	5 787	55.1
Under 50 per cent non-resident	105	46.3	4 599	43.8
Government business enterprise	2	0.9	. .	. .
Other corporations	70	30.8	. .	. .
Total, all corporations	227	100.0	10 504	100.0
Mineral fuels				
Reporting corporations				
50 per cent and over non-resident	220	26.1	6 675	74.0
Under 50 per cent non-resident	250	29.6	2 225	24.7
Government business enterprise	3	0.4	90	1.0
Other corporations	370	43.9	24	0.3
Total, all corporations	843	100.0	9 014	100.0
Other mining (including mining services)				
Reporting corporations				
50 per cent and over non-resident	182	6.3	2 048	58.4
Under 50 per cent non-resident	994	34.7	1 268	36.2
Government business enterprise	3	0.1	. .	. .
Other corporations	1 689	58.9	. .	. .
Total, all corporations	2 868	100.0	3 503	100.0
Total mining				
Reporting corporations				
50 per cent and over non-resident	452	11.5	14 510	63.0
Under 50 per cent non-resident	1 349	34.3	8 092	35.2
Government business enterprise	8	0.2	252	1.1
Other corporations	2 129	54.0	167	0.7
Total, all corporations	3 938	100.0	23 021	100.0

Note: Footnotes for Table 64 apply to this table.
[1]Classification of the industry is the same as in Table 27. . . Not available or not applicable; — Nil.

by degree of non-resident ownership, 1974

Equity		Sales		Profits		Taxable Income	
($ million)	(%)	($ million)	(%)	($ million)	(%)	($ million)	(%)
2 667	49.3	2 930	55.5	813	53.7	154.3	21.2
2 692	49.8	2 310	43.8	699	46.1	574.8	78.8
. .	. .	. .	. .	. .	. .	—	—
. .	. .	. .	. .	. .	. .	0.1	0.01
5 407	100.0	5 280	100.0	1 515	100.0	729.2	100.0
3 799	74.8	4 501	88.7	875	85.9	706.3	88.5
1 226	24.2	534	10.5	149	14.6	90.4	11.3
69	1.3	26	0.5	-2	-0.2	—	—
-13	-0.3	15	0.3	-3	-0.3	1.8	0.2
5 081	100.0	5 076	100.0	1 019	100.0	798.5	100.0
1 119	55.9	1 053	61.9	229	86.1	135.9	80.1
794	39.7	552	32.5	40	15.0	27.3	16.1
. .	. .	. .	. .	. .	. .	—	—
. .	. .	. .	. .	. .	. .	6.5	3.8
2 000	100.0	1 700	100.0	266	100.0	169.7	100.0
7 585	60.8	8 484	70.4	1 917	68.5	996.5	58.7
4 712	37.7	3 396	28.2	888	31.7	692.5	40.8
163	1.3	74	0.6	5	0.2	—	—
28	0.2	102	0.8	—10	—0.4	8.4	0.5
12 488	100.0	12 056	100.0	2 800	100.0	1 697.4	100.0

Table 64. Canada, financial statistics of corporations in the mineral manufacturing

	Corporations[2]		Assets[5]	
	(Number)	(%)	($ million)	(%)
Primary metal products				
Reporting corporations[2]				
50% and over non-resident	55	11.3	2 369	37.9
Under 50% non-resident	203	41.9	3 871	62.0
Government business enterprises[3]	2	0.4	. .	. .
Other[4]	225	46.4	. .	. .
Total, all corporations	485	100.0	6 246	100.0
Nonmetallic mineral products				
Reporting corporations[2]				
50% and over non-resident	104	8.9	1 728	62.4
under 50% non-resident	504	43.0	982	35.4
Government business enterprises[3]	2	0.2	. .	. .
Others[4]	561	47.9	. .	. .
Total, all corporations	1 171	100.0	2 771	100.0
Petroleum and coal products				
Reporting corporations[2]				
50% and over non-resident	22	40.8	10 153	97.7
under 50% non-resident	18	33.3	240	2.3
Government business enterprises[3]	—	—	—	—
Other[4]	14	25.9	1	0.01
Total, all corporations	54	100.0	10 394	100.0
Total mineral manufacturing industries				
Reporting companies[2]				
50% and over non-resident	181	10.6	14 250	73.4
under 50% non-resident	725	42.4	5 093	26.2
Government business enterprises[3]	4	0.2	. .	. .
Other[4]	800	46.8	. .	. .
Total, all corporations	1 710	100.0	19 411	100.0

[1]Classification of industries is the same as in Table 28. [2]Corporations reporting under the Corporations and Labour Unions Returns Act. A corporation is considered to be foreign controlled if 50% or more of its voting rights are known to be held outside Canada, and/or by one or more Canadian corporations which are, in turn, foreign controlled. Each corporation is classified according to the percentage of its voting rights which are owned by non-residents, either directly or through other Canadian corporations, and the whole of the corporation is assigned to this particular degree of foreign ownership. [3]Non-taxable federal and provincial Crown Corporations and municipally-owned corporations. [4]Corporations exempt from reporting under the Corporations and Labour Unions Returns Act. These include corporations reporting under other acts, small companies and corporations, and non-profit organizations. [5]Included are cash, marketable securities, accounts receivable, inventories, fixed assets, investments in affiliated corporations and other assets. The amounts tabulated are those shown on the balance sheets of corporations after deducting allowances for doubtful accounts, amortization, depletion and depreciation. [6]Equity represents the shareholders' interest in the net assets of the corporation and includes the total amount of all issued and paid-up share capital, earnings retained in the business, and other surplus accounts such as contributed and capital surplus. [7]For non-financial corporations, sales are gross revenues from non-financial operations. For financial corporations sales include income from financial as well as non-financial sources. [8]The net earnings from operations, investment income and net capital gains. Profits are tabulated after deducting allowances for amortization, depletion and depreciation, but before income tax provisions or declaration of dividends. [9]Taxable income figures are as reported by corporations prior to assessment by the Department of National Revenue. They include earnings in the reference year after the deduction of applicable losses of other years.
— Nil; . . Not available or not applicable; — — Amount too small to be expressed.

industries,[1] by degree of non-resident ownership, 1974

Equity[6]		Sales[7]		Profits[8]		Taxable Income[9]	
($ million)	(%)	($ million)	(%)	($ million)	(%)	($ million)	(%)
1 099	37.8	2 031	35.8	241	36.2	99.2	37.3
1 711	58.9	3 544	62.5	379	57.0	164.5	61.8
. .	. .	. .	. .	. .	. .	—	—
. .	. .	. .	. .	. .	. .	2.4	0.9
2 905	100.0	5 673	100.0	665	100.0	266.1	100.0
965	71.6	1 352	51.7	188	67.4	103.4	66.9
358	26.6	1 183	45.2	88	31.5	46.4	30.0
. .	. .	. .	. .	. .	. .	—	—
. .	. .	. .	. .	. .	. .	4.7	3.1
1 348	100.0	2 616	100.0	279	100.0	154.5	100.0
5 165	98.2	10 195	97.9	1 511	97.1	1 125.7	99.7
97	1.8	222	2.1	45	2.9	3.0	0.3
—	—	—	—	—	—	—	—
— —	— —	3	0.03	—	—	0.2	0.02
5 262	100.0	10 420	100.0	1 556	100.0	1 128.9	100.0
7 229	76.0	13 578	72.6	1 940	77.6	1 328.3	85.7
2 166	22.8	4 949	26.5	512	20.5	213.9	13.8
. .	. .	. .	. .	. .	. .	—	—
. .	. .	. .	. .	. .	. .	7.3	0.5
9 515	100.0	18 709	100.0	2 500	100.0	1 549.5	100.0

Table 65. Canada, financial statistics of corporations in non-financial industries,

		Agriculture, Forestry, Fishing and Trapping		Mining		Manufacturing	
		1973	1974^p	1973	1974^p	1973	1974^p
Number of corporations							
Foreign control	number	102	105	476	452	2 288	2 360
Canadian control	number	2 466	3 077	1 306	1 349	8 664	10 172
Other corporations	number	6 171	6 568	2 174	2 137	13 659	13 961
Total corporations	number	8 739	9 750	3 956	3 938	24 611	26 493
Assets							
Foreign control	$ million	240	267	11 104	14 510	34 081	41 173
Canadian control	$ million	1 445	1 824	9 101	8 092	24 212	29 485
Other corporations	$ million	599	645	379	419	1 770	2 109
Total corporations	$ million	2 284	2 736	20 584	23 021	60 063	72 767
Equity							
Foreign control	$ million	112	116	6 338	7 585	17 570	19 997
Canadian control	$ million	496	610	5 467	4 712	10 336	11 918
Other corporations	$ million	144	159	173	191	404	485
Total corporations	$ million	751	885	11 978	12 488	28 311	32 400
Sales							
Foreign control	$ million	181	203	5 158	8 484	43 313	54 547
Canadian control	$ million	1 306	1 682	3 812	3 396	31 601	39 919
Other corporations	$ million	529	604	147	176	2 182	2 430
Total corporations	$ million	2 016	2 489	9 117	12 056	77 096	96 896
Profits							
Foreign control	$ million	16	14	1 007	1 917	3 907	5 402
Canadian control	$ million	156	132	1 087	888	2 635	3 198
Other corporations	$ million	40	40	−14	−5	66	69
Total corporations	$ million	212	186	2 080	2 800	6 607	8 669

Note: Figures may not add due to rounding.
^{p}Preliminary.

by major industry group and by control, 1973 and 1974

Construction		Transportation, Communication and other Utilities		Trade		Services		Total	
1973	1974[p]	1973	1974[p]	1973	1974[p]	1973	1974[p]	1973	1974[p]
170	196	243	270	1 744	1 908	521	566	5 544	5 857
6 467	8 101	2 302	2 754	17 556	22 084	6 219	7 762	44 980	55 299
19 902	21 481	8 425	8 918	49 502	50 074	33 016	35 682	132 849	138 821
26 539	29 778	10 970	11 942	68 802	74 066	39 756	44 010	183 373	199 977
1 190	1 541	3 081	2 492	7 966	9 205	2 611	3 070	60 273	72 256
6 804	9 203	18 692	22 286	17 344	22 538	6 174	7 755	83 772	101 183
1 322	1 456	29 896	33 339	4 748	6 355	2 071	2 288	40 786	46 613
9 316	12 200	51 669	58 117	30 058	38 098	10 856	13 113	184 830	220 051
317	390	1 154	945	3 040	3 234	1 051	1 234	29 581	33 504
1 419	1 784	7 310	8 289	5 898	7 323	2 100	2 374	33 026	37 009
393	435	7 258	8 113	1 354	1 421	610	668	10 334	11 471
2 129	2 609	15 722	17 347	10 291	11 978	3 761	4 276	72 941	81 984
1 453	1 867	1 297	1 308	16 191	19 401	2 145	2 660	69 739	88 470
9 079	12 026	7 988	10 227	43 815	58 448	4 761	6 511	102 363	132 208
2 567	2 905	6 907	7 984	9 762	11 807	2 769	3 244	24 863	29 150
13 099	16 798	16 193	19 519	69 769	89 656	9 675	12 415	196 965	249 828
97	92	196	196	601	950	253	493	6 076	9 064
361	563	1 167	1 346	1 433	2 055	292	427	7 131	8 609
108	138	378	400	940	1 077	176	215	1 691	1 934
566	793	1 741	1 942	2 973	4 082	721	1 135	14 899	19 607

Table 66. Canada, capital and repair expenditures in mining[1] and mineral manufacturing industries, 1975-77

	1975			1976[p]			1977[f]		
	Capital	Repair	Total	Capital	Repair	Total	Capital	Repair	Total
					($ million)				
Mining industry									
Metal mines									
Gold	26.0	11.7	37.7	21.4	10.6	32.0	20.2	10.6	30.8
Silver-lead-zinc	84.6	30.9	115.5	64.9	38.7	103.6	87.1	41.2	128.3
Copper-gold-silver	161.0	135.4	296.4	197.4	137.6	335.0	207.7	151.0	358.7
Iron	309.6	211.8	521.4	. .	225.9	. .	. .	231.4	. .
Other metal mines	133.7	120.6	254.3	562.4	135.4	923.7[5]	664.3	149.5	1 045.2[5]
Total metal mines	714.9	510.4	1 225.3	846.1	548.2	1 394.3	979.3	583.7	1 563.0
Nonmetal mines									
Asbestos	61.8	50.1	111.9	93.7	75.4	169.1	111.3	79.2	190.5
Other nonmetal mines[2]	260.6	158.0	418.6	237.8	156.0	393.8	285.1	171.0	456.1
Total nonmetal mines	322.4	208.1	530.5	331.5	231.4	562.9	396.4	250.2	646.6
Mineral fuels									
Petroleum and gas[3]	1 574.7	283.7	1 858.4	2 270.1	278.5	2 548.6	2 749.4	314.0	3 063.4
Total mining industries	2 612.0	1 002.2	3 614.2	3 447.7	1 058.1	4 505.8	4 125.1	1 147.9	5 273.0
Mineral manufacturing									
Primary metal industries									
Iron and steel mills	541.7	368.0	909.7	442.8	407.8	850.6	394.0	437.8	831.8
Steel pipe and tube mills	19.1	29.0	48.1	11.9	29.8	41.7	21.8	31.4	53.2
Iron foundries	26.2	23.8	50.0	19.4	22.7	42.1	30.7	22.1	52.8
Smelting and refining	134.7	187.2	321.9	108.7	201.6	310.3	206.6	238.0	444.6
Aluminum rolling, casting and extruding	20.6	11.2	31.8	9.8	13.1	22.9	20.2	15.2	35.4
Other primary metal industries	72.6	10.0	82.6	21.8	11.8	33.6	12.0	12.3	24.3
Total primary metal industries	814.9	629.2	1 444.1	614.4	686.8	1 301.2	685.3	756.8	1 442.1

Table 66. (concl'd)

	1975			1976[p]			1977[f]		
	Capital	Repair	Total	Capital	Repair	Total	Capital	Repair	Total
	($ million)								
Nonmetallic mineral products									
Cement	54.8	33.6	88.4	82.3	36.5	118.8	94.9	41.4	136.3
Lime[4]	. .	. .	. .	. .	. .	. .	. .	. .	. .
Gypsum products[4]	. .	. .	. .	. .	. .	. .	. .	. .	. .
Concrete products	32.3	41.9	74.2	27.1	29.1	56.2	24.2	27.8	52.0
Ready mix concrete	37.5	37.3	74.8	33.5	31.2	64.7	38.3	33.7	72.0
Clay products	17.6	5.6	23.2	6.4	5.7	12.1	8.6	7.1	15.7
Refractories[4]	. .	. .	. .	. .	. .	. .	. .	. .	. .
Asbestos[4]	. .	. .	. .	. .	. .	. .	. .	. .	. .
Glass and glass products	17.0	14.6	31.6	32.0	10.1	42.1	23.7	11.4	35.1
Abrasives	7.8	8.3	16.1	6.1	10.2	16.3	4.3	10.2	14.5
Other nonmetallic mineral products	32.1	24.9	57.0	52.3	28.1	80.4	76.0	31.5	107.5
Total nonmetallic mineral products	199.1	166.2	365.3	239.7	150.9	390.6	270.0	163.1	433.1
Petroleum and coal products	450.4	133.1	583.5	355.2	133.3	488.5	414.5	159.0	573.5
Total mineral manufacturing industries	1 464.4	928.5	2 392.9	1 209.3	971.0	2 180.3	1 369.8	1 078.9	2 448.7
Total mining and mineral manufacturing industries	4 076.4	1 930.7	6 007.1	4 657.0	2 029.1	6 686.1	5 494.9	2 226.8	7 721.7

[1]Does not include cement, lime and clay products (domestic clay) manufacturing, smelting and refining. [2]Includes coal mines, gypsum, salt, potash and miscellaneous nonmetal mines and quarrying. [3]The total of capital expenditures shown under "petroleum and gas" is equal to the total capital expenditure under the column entitled "petroleum and natural gas extraction" and under the column "natural gas processing plants" of Table 69. [4]Shown separately during past years, but included in other nonmetallic mineral products for 1975-1977. [5]Includes repair expenditures of iron mines.
[p]Preliminary; [f]Forecast; . . . Not available.

Table 67. Canada, capital and repair expenditures in the mining industry,[1] 1967-77

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]	1977[f]
						($ million)					
Metal mines											
Capital											
Construction	238.1	264.8	295.1	335.6	590.8	345.7	357.1	409.6	499.6	487.4	476.4
Machinery	131.3	105.2	98.2	150.3	239.8	313.0	241.3	157.9	215.3	358.7	502.9
Total	369.4	370.0	393.3	485.9	830.6	658.7	598.4	567.5	714.9	846.1	979.3
Repair											
Construction	33.4	47.9	35.7	36.6	38.9	26.4	48.0	58.7	63.7	66.8	70.6
Machinery	116.6	152.2	160.9	220.2	240.9	242.4	299.7	383.4	446.7	481.4	513.1
Total	150.0	200.1	196.6	256.8	279.8	268.8	347.7	442.1	510.4	548.2	583.7
Total capital and repair	519.4	570.1	589.9	742.7	1 110.4	927.5	946.1	1 009.6	1 225.3	1 394.3	1 563.0
Nonmetal mines[2]											
Capital											
Construction	121.1	110.2	128.1	107.9	84.6	59.8	67.5	116.0	112.8	127.4	170.5
Machinery	85.4	128.4	113.9	115.9	105.6	81.3	79.7	125.7	209.6	204.1	225.9
Total	206.5	238.6	242.0	223.8	190.2	141.1	147.2	241.7	322.4	331.5	396.4
Repair											
Construction	4.5	4.3	10.4	7.1	7.9	6.2	6.5	13.1	23.8	23.8	24.5
Machinery	57.0	57.5	64.7	99.9	107.1	116.4	135.2	167.0	184.3	207.6	225.7
Total	61.5	61.8	75.1	107.0	115.0	122.6	141.7	180.1	208.1	231.4	250.2
Total capital and repair	268.0	300.4	317.1	330.8	305.2	263.7	288.9	421.8	530.5	562.9	646.6
Mineral fuels											
Capital											
Construction	403.0	407.4	465.3	552.6	639.4	729.3	851.7	1 060.9	1 355.7	1 780.2	2 226.4
Machinery	71.8	58.0	76.6	86.2	101.3	91.2	83.4	165.3	219.0	489.9	523.0
Total	474.8	465.4	541.9	638.8	740.7	820.5	935.1	1 226.2	1 574.7	2 270.1	2 749.4

Table 67. (concl'd)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]	1977[f]
						($ million					
Repair											
Construction	34.2	56.3	73.7	93.5	102.7	106.8	138.0	159.0	215.2	196.7	227.0
Machinery	14.7	19.2	19.0	22.5	28.7	35.6	54.2	62.3	68.5	81.8	87.0
Total	48.9	75.5	92.7	116.0	131.4	142.4	192.2	221.3	283.7	278.5	314.0
Total capital and repair	523.7	540.9	634.6	754.8	872.1	962.9	1 127.3	1 447.5	1 858.4	2 548.6	3 063.4
Total mining											
Capital											
Construction	762.2	782.4	888.5	996.1	1 314.8	1 134.8	1 276.3	1 586.5	1 968.1	2 395.0	2 873.3
Machinery	288.5	291.6	288.7	352.4	446.7	485.5	404.4	448.9	643.9	1 052.7	1 251.8
Total	1 050.7	1 074.0	1 177.2	1 348.5	1 761.5	1 620.3	1 680.7	2 035.4	2 612.0	3 447.7	4 125.1
Repair											
Construction	72.1	108.5	119.8	137.2	149.5	139.4	192.5	230.8	302.7	287.3	322.1
Machinery	188.3	228.9	244.6	342.6	376.7	394.4	489.1	612.7	699.5	770.8	825.8
Total	260.4	337.4	364.4	479.8	526.2	533.8	681.6	843.5	1 002.2	1 058.1	1 147.9
Total capital and repair	1 311.1	1 411.4	1 541.6	1 828.3	2 287.7	2 154.1	2 362.3	2 878.9	3 614.2	4 505.8	5 273.0

[1]Does not include cement, lime and clay products (domestic clays) manufacturing, smelting and refining. [2]Includes coal mines, asbestos, gypsum, salt, potash, miscellaneous nonmetals, quarrying and sand pits.
[p]Preliminary; [f]Forecast.

Table 68. Canada, capital and repair expenditures in the mineral manufacturing industries[1], 1967-77

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]	1977[f]
						($ million)					
Primary metal industries[2]											
Capital											
Construction	82.0	77.5	71.5	114.0	89.0	95.3	75.8	148.0	200.5	147.3	140.4
Machinery	202.8	157.9	221.4	311.2	312.4	276.6	328.5	549.7	614.4	467.1	544.9
Total	284.8	235.4	292.9	425.2	401.4	371.9	404.3	697.7	814.9	614.4	685.3
Repair											
Construction	24.9	27.7	22.6	28.6	28.4	35.3	38.8	51.6	65.8	60.9	69.2
Machinery	258.1	281.4	267.9	324.6	343.5	383.2	420.1	507.3	563.4	625.9	687.6
Total	283.0	309.1	290.5	353.2	371.9	418.5	458.9	558.9	629.2	686.8	756.8
Total capital and repair	567.8	544.5	583.4	778.4	773.3	790.4	863.2	1 256.6	1 444.1	1 301.2	1 442.1
Nonmetallic mineral products[3]											
Capital											
Construction	39.5	19.6	37.1	30.7	21.8	30.7	37.6	29.5	41.1	46.8	57.9
Machinery	80.3	66.5	84.0	104.3	58.5	99.2	151.1	144.7	158.0	192.9	212.1
Total	119.8	86.1	121.1	135.0	80.3	129.9	188.7	174.2	199.1	239.7	270.0
Repair											
Construction	9.3	7.2	7.2	5.4	7.0	8.5	7.5	11.3	14.4	13.3	14.4
Machinery	63.9	73.8	72.1	77.1	80.4	85.7	112.0	130.9	151.8	137.6	148.7
Total	73.2	81.0	79.3	82.5	87.4	94.2	119.5	142.2	166.2	150.9	163.1
Total capital and repair	193.0	167.1	200.4	217.5	167.7	224.1	308.2	316.4	365.3	390.6	433.1
Petroleum and coal products											
Capital											
Construction	78.8	99.0	116.9	213.7	211.3	214.0	229.7	321.7	337.5	265.2	309.3
Machinery	21.4	28.8	12.9	17.4	20.1	29.8	89.1	107.8	112.9	90.0	105.2
Total	100.2	127.8	129.8	231.1	231.4	243.8	318.8	429.5	450.4	355.2	414.5

Table 68. (concl'd)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976[p]	1977[f]
	($ million)										
Repair											
Construction	36.0	46.6	52.1	51.0	51.3	61.3	71.1	83.8	96.1	98.8	117.0
Machinery	10.2	8.6	6.8	9.2	9.8	14.6	17.3	27.0	37.0	34.5	42.0
Total	46.2	55.2	58.9	60.2	61.1	75.9	88.4	110.8	133.1	133.3	159.0
Total capital and repair	146.4	183.0	188.7	291.3	292.5	319.7	407.2	540.3	583.5	488.5	573.5
Total mineral manufacturing industries											
Capital											
Construction	200.3	196.1	225.5	358.4	322.1	340.0	343.1	499.2	579.1	459.3	507.6
Machinery	304.5	253.2	318.3	432.9	391.0	405.6	568.7	802.2	885.3	750.0	862.2
Total	504.8	449.3	543.8	791.3	713.1	745.6	911.8	1 301.4	1 464.4	1 209.3	1 369.8
Repair											
Construction	70.2	81.5	81.9	85.0	86.7	105.1	117.4	146.7	176.3	173.0	200.6
Machinery	332.2	363.8	346.8	410.9	433.7	483.5	549.4	665.2	752.2	798.0	878.3
Total	402.4	445.3	428.7	495.9	520.4	588.6	666.8	811.9	928.5	971.0	1 078.9
Total capital and repair	907.2	894.6	972.5	1 287.2	1 233.5	1 334.2	1 578.6	2 133.3	2 392.9	2 180.3	2 448.7

[1]Industry groups are the same as in Table 28. [2]Includes smelting and refining. [3]Includes cement, lime and clay products manufacturing.
[p]Preliminary; [f]Forecast.

Table 69. Canada, capital expenditures in the petroleum, natural gas and allied industries[1], 1966-77

	Petroleum and natural gas extraction[2]	Transportation including rail, water and pipelines	Marketing (chiefly outlets of oil companies)	Natural gas distribution	Petroleum and coal products industries	Natural gas processing plants	Total capital expenditures
				($ million)			
1966	453.5	154.0	64.0	92.3	65.1	50.1	879.0
1967	385.1	204.9	86.8	76.4	100.2	89.7	943.1
1968	374.3	247.9	87.6	117.4	127.6	91.1	1 045.9
1969	438.1	220.6	103.6	117.0	129.8	103.8	1 112.9
1970	449.3	246.5	100.0	100.4	231.1	189.5	1 316.8
1971	489.6	352.0	99.2	115.2	231.4	251.1	1 538.5
1972	690.2	440.9	111.8	141.7	243.8	130.3	1 758.7
1973	864.8	390.9	128.0	146.3	318.8	70.3	1 919.1
1974	1 087.8	262.4	144.7	191.7	429.5	138.4	2 254.5
1975	1 427.2	499.3	152.8	192.7	450.4	147.5	2 819.9
1976[p]	2 109.1	419.5	152.2	188.9	355.2	161.0	3 385.9
1977[f]	2 516.2	494.4	158.8	209.6	414.5	233.2	4 026.7

[1]The petroleum and natural gas industries in this table include all companies engaged in whole or in part in oil and gas activities. [2]Includes capital expenditures by oil and gas drilling contractors since 1966. Does not include expenditures for geological and geophysical operations. See also Footnote 3 to Table 66.
[p]Preliminary; [f]Forecast.

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